The Effect of Instrument Approach Procedure Chart Design on Pilot Search Speed and Response Accuracy: Flight Test Results

DOT/FAA/AR-95/8
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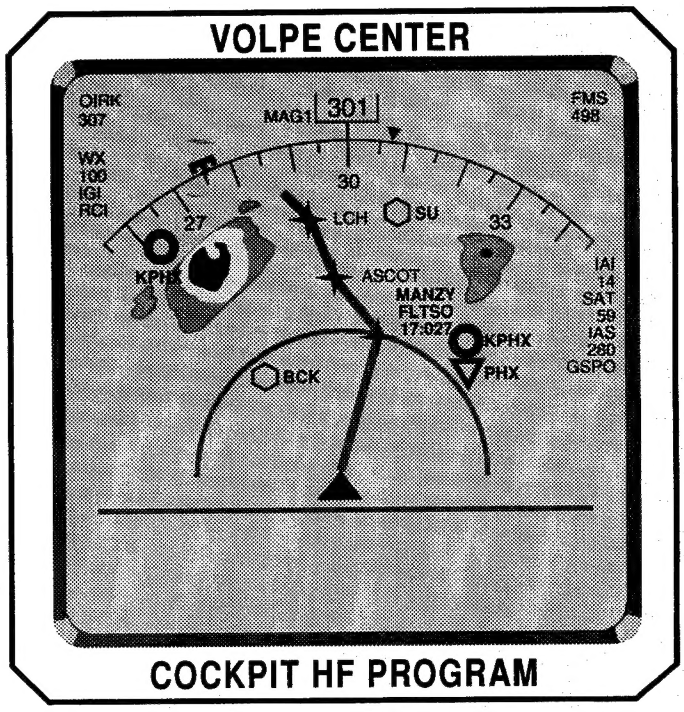
Office of Aviation Research
Washington, DC 20591



U.S. Department of Transportation
Research and Special Programs Administration
John A. Volpe National Transportation Systems Center
Cambridge, MA 02142

Final Report
June 1995

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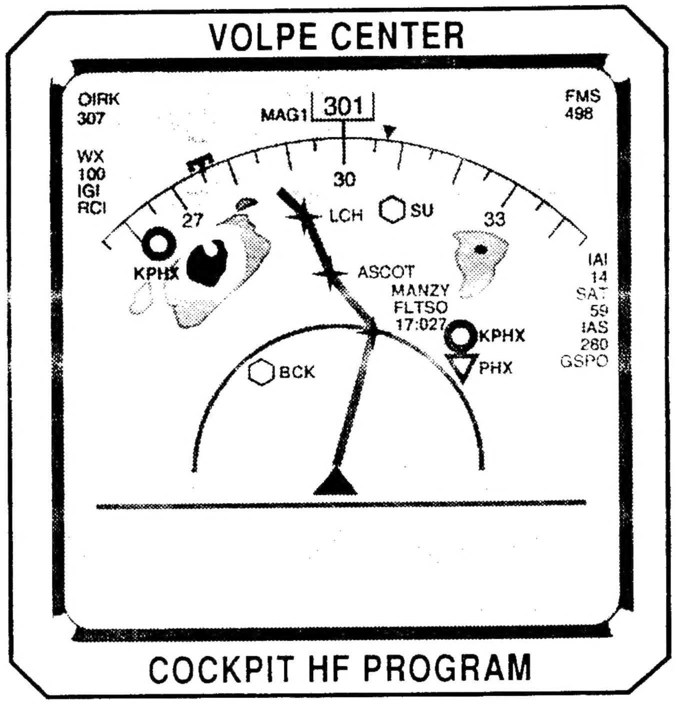

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13. ABSTRACT (Maximum 200 words)
Instrument approach procedure (IAP) charts can be densely packed with information. This high information density can make information difficult to find, particularly in a poorly lit cockpit during turbulence. The Volpe Center's Cockpit Human Factors Program conducted a series of evaluations to format IAP chart information to more closely conform to the way pilots actually use the information. All of this work has contributed to the evolution of the Volpe prototype IAP chart format. The prototype's major design features are the briefing strip and iconic missed approach procedure instructions. The briefing strip consists of three rows of tabularized information at the top of the chart. This feature is designed primarily for use in preparing for the approach. Each information element is given in the order in which it will be used. The pilot no longer has to search through the entire chart to assemble this data. In the profile view, the "up and out" portion of the missed approach instructions is depicted in icons rather than text. This critical information is more easily located than if it were embedded in text. The objective of this study was to determine if the prototype IAP chart format would allow pilots to find information faster and more accurately during actual flight. Ten licensed pilots rated for instrument flight participated as subjects in this experiment. Each of the approaches were depicted in two chart formats: National Ocean Service (NOS) and the Volpe prototype.

Pilots took advantage of the prototype's briefing strip to search for information to answer questions. They found information faster on the prototype chart than on the NOS chart. No difference was found between the accuracy of the answers given when pilots used the prototype and when they used the NOS format. Pilots found information regarding the "up and out" portion of the missed approach instructions faster when they used the iconic missed approach instructions on the prototype chart than when they used text instructions on the NOS chart. All pilots preferred the prototype format for executing the missed approach because of the iconic instructions. Most pilots preferred the prototype format for studying for the approach. None of the pilots preferred the NOS format for executing any approach phase.

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instrument approach procedure charts, prototype charts, briefing strip, icons, human factors, information transfer

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PREFACE

This report describes an experiment which examined the effects of instrument approach procedure (IAP) chart design on pilot search speed and response accuracy. Ten pilots currently licensed for instrument flight participated as subjects. Pilots used charts depicted in either National Ocean Service (NOS) format or a prototype format to fly a series of instrument approaches. During these approaches, pilots were asked a set of questions pertaining to the charted information. Pilots were able to find information faster on the prototype chart than on the NOS chart, and they indicated a clear preference for the prototype format over the NOS format. These findings are consistent with the outcome of past research.

This is the final effort in a series of evaluations by the Volpe Center Cockpit Human Factors Program to format IAP chart information to more closely conform to the way pilots actually use the information. This report was sponsored by the Federal Aviation Administration's human factors program under the Office of Chief Scientific and Technical Advisor for Human Factors.

The report was prepared for the Operator Performance and Safety Analysis Division of the Office of Research and Analysis at the Volpe Center (John A. Volpe National Transportation Systems Center), and was completed under the direction of M. Stephen Huntley, Jr., Volpe Center Cockpit Human Factors Program Manager. The research and report preparation were the responsibility of David W. Osborne, EG&G Dynatrend.

METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in)	= 2.5 centimeters (cm)
1 foot (ft)	= 30 centimeters (cm)
1 yard (yd)	= 0.9 meter (m)
1 mile (mi)	= 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2)	= 6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2)	= 0.09 square meter (m^2)
1 square yard (sq yd, yd^2)	= 0.8 square meter (m^2)
1 square mile (sq mi, mi^2)	= 2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he)	= 4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz)	= 28 grams (gm)
1 pound (lb)	= 0.45 kilogram (kg)
1 short ton = 2,000 pounds (lb)	= 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp)	= 5 milliliters (ml)
1 tablespoon (tbsp)	= 15 milliliters (ml)
1 fluid ounce (fl oz)	= 30 milliliters (ml)
1 cup (c)	= 0.24 liter (l)
1 pint (pt)	= 0.47 liter (l)
1 quart (qt)	= 0.96 liter (l)
1 gallon (gal)	= 3.8 liters (l)
1 cubic foot (cu ft, ft^3)	= 0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3)	= 0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm)	= 0.04 inch (in)
1 centimeter (cm)	= 0.4 inch (in)
1 meter (m)	= 3.3 feet (ft)
1 meter (m)	= 1.1 yards (yd)
1 kilometer (k)	= 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2)	= 0.16 square inch (sq in, in^2)
1 square meter (m^2)	= 1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2)	= 0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2)	= 1 hectare (he) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm)	= 0.036 ounce (oz)
1 kilogram (kg)	= 2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg)	= 1.1 short tons

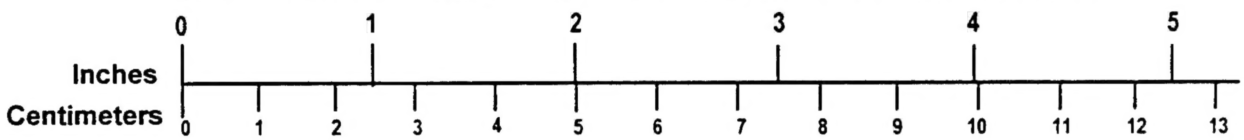
VOLUME (APPROXIMATE)

1 milliliter (ml)	= 0.03 fluid ounce (fl oz)
1 liter (l)	= 2.1 pints (pt)
1 liter (l)	= 1.06 quarts (qt)
1 liter (l)	= 0.26 gallon (gal)
1 cubic meter (m^3)	= 36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3)	= 1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NBS Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

Updated 1/23/95

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EXECUTIVE SUMMARY

Instrument approach procedure (IAP) charts can be densely packed with information. This high information density can make information difficult to find, particularly in a poorly lit cockpit during turbulence. The workload imposed by operations in the terminal area compounds the legibility problem by reducing the amount of time pilots have to search for information, and by reducing the amount of attention resources pilots can focus on chart interpretation.

The Volpe Center's Cockpit Human Factors Program conducted a series of evaluations to format IAP chart information to more closely conform to the way pilots actually use the information. All of this work has contributed to the evolution of the Volpe prototype IAP chart format. The prototype's major design features are the briefing strip and iconic missed approach procedure instructions. The briefing strip consists of three rows of tabularized information at the top of the chart. This feature is designed primarily for use in preparing for the approach. Each information element is given in the order in which it will be used. The pilot no longer has to search through the entire chart to assemble this data. In the profile view, the "up and out" portion of the missed approach instructions is depicted in icons rather than text. These icons tell the pilot all that is required to get the plane up and out - and this critical information is more easily located than if it were embedded in text.

The purpose of the prototype is to improve the speed and accuracy with which pilots find information on IAP charts. The objective of this study was to determine if the prototype IAP chart format would allow pilots to find information faster and more accurately during actual flight.

Ten licensed pilots rated for instrument flight participated as subjects in this experiment. Each of the approaches were depicted in two chart formats: National Ocean Service (NOS) and the Volpe prototype. Each approach was based on an actual approach taken from the U.S. Terminal Procedures charts published by the U.S. National Oceanic and Atmospheric Administration. Non-precision approaches from around the United States were selected for the study. Global Positioning System (GPS) overlay approaches were constructed for the airport where the study was conducted because it was not possible to use actual VOR or NDB approaches for this experiment.

Pilots participated for two days. The first day consisted of training in a simulator, during which the pilots gained experience in using the prototype chart format, flying with guidance from a GPS receiver, and having someone ask them a series of questions while flying an approach. Data collection during actual flight occurred on the second day. Both days were composed of a morning session and an afternoon session. In each session, pilots were exposed to only one chart format (NOS or prototype). All pilots received training for and flew with both chart formats.

Pilots took advantage of the prototype's briefing strip to search for information to answer questions. They found information faster on the prototype chart than on the NOS chart. No difference was found between the accuracy of the answers given when pilots used the

prototype and when they used the NOS format. Pilots found information regarding the "up and out" portion of the missed approach instructions faster when they used the iconic missed approach instructions on the prototype chart than when they used text instructions on the NOS chart.

Most pilots preferred the prototype format for studying for the approach. All pilots preferred the prototype format for executing the missed approach because of the iconic instructions. None of the pilots preferred the NOS format for executing any approach phase.

These findings are consistent with the outcome of past laboratory experimentation, subject matter expert interviews, a review of the relevant literature, and a field evaluation using simulators. The National Ocean Service is strongly urged to adopt the prototype format for its IAP charts.

1. INTRODUCTION

1.1 THE PROBLEM

Instrument approach procedure (IAP) charts provide pilots with the information required to fly an instrument approach procedure to a runway of intended landing, and if necessary, to fly the missed approach procedure (International Civil Aviation Organization, 1985). The U.S. Department of Commerce National Ocean Service (NOS) is a major manufacturer of IAP charts. An example of a NOS IAP chart, the instrument landing system approach to runway 25 at Los Angeles International Airport, is given in Figure 1.

As this figure illustrates, IAP charts can be densely packed with information. This high information density can make information difficult to find, particularly in a poorly lit cockpit during turbulence. The workload imposed by operations in the terminal area compounds the legibility problem by reducing the amount of time pilots have to search for information, and by reducing the amount of attention resources pilots can focus on chart interpretation. Cox and Connor (1987) surveyed pilots regarding human factors problems they have encountered with IAP charts. The authors stated that "Inefficient information transfer techniques used in charting approach, missed approach, and instrument departure procedures and associated information are causing ... excessive head-in-the-cockpit time ... that could have ... adverse impact on air safety ..." (p. 11).

1.2 HOW THE VOLPE PROTOTYPE IAP CHART FORMAT WAS DEVELOPED

The Volpe Center's Cockpit Human Factors Program conducted a series of evaluations of both individual chart components and the Volpe prototype as a whole. The goal was to format the information to more closely conform to the way pilots actually use the information. This work has been accomplished by taking four approaches: laboratory experimentation, subject matter expert evaluations, a review of the relevant literature, and a field evaluation conducted at the training centers of four airlines.

Multer, Warner, DiSario, and Huntley (1991) conducted two studies in IAP chart design. The first study examined three different methods of presenting the final approach course: bolding (increasing the line weight of the text), boxing, and reverse contrast (white text in a black box). Both boxing and reverse contrast improved the speed with which pilots could find items on IAP charts. Reverse contrast was so compelling that the authors stated that it might detract from a pilot's search performance if the item printed in reverse contrast was not the item being searched for. Therefore, the prototype highlights the final approach course by boxing it.

The second study conducted by Multer, et. al. addressed the effects of four different layouts of radio frequencies. Text size and type of font were held constant. The four layouts were: frequency under the name (similar to current NOS format); frequency to the right of the name (similar to current Jeppesen format); frequency to the right of the name, with the name and frequencies in their own left-justified columns; and frequency under the name with both

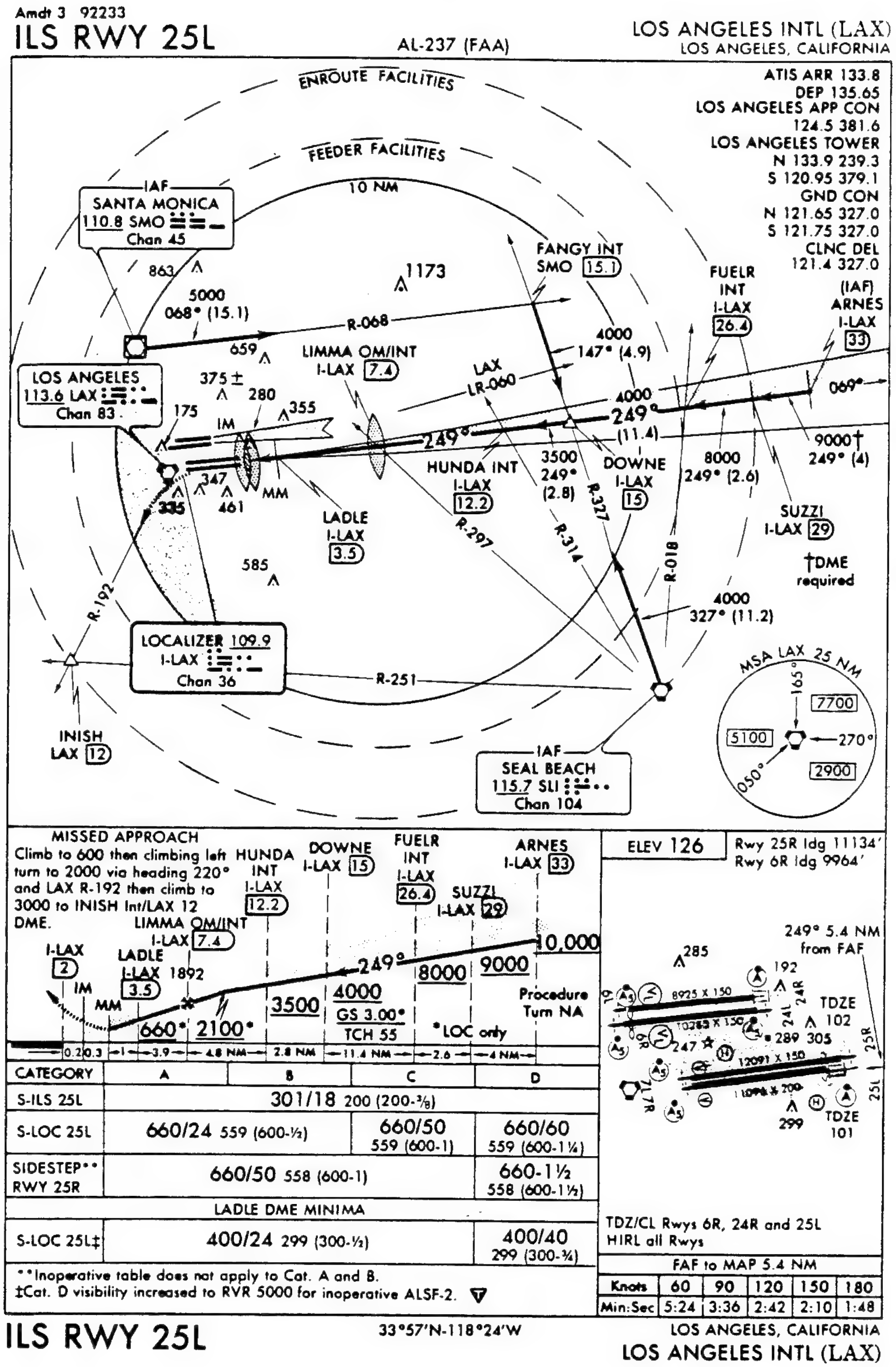

Figure 1. National Ocean Service IAP Chart for the Instrument Landing System (ILS) Approach to Runway 25 Left at Los Angeles International Airport

boxed and centered within the box (similar to Canadian Department of Energy, Mines and Resources IAP charts). Pilots found the desired frequencies faster with the two column and boxed layouts than with the other two layouts. The prototype format uses the boxed and centered method to format the radio frequencies.

Osborne and Huntley (1992) conducted an experiment to determine if encoding the missed approach instructions in icons would allow pilots to comprehend the instructions faster and more accurately than text instructions. They also examined the effect of varying the amount of information (low, medium, or high) in the instructions on comprehension speed and accuracy. Across the range of information content levels, iconic missed approach instructions were comprehended more quickly and as accurately as instructions coded in text of the font style and size used by NOS. Regardless of encoding method, report accuracy was worse for instructions with a high information content level. These results were implemented in the prototype format by using icons to code the initial ("up and out") portion of the missed approach instructions.

Throughout its development, the prototype IAP chart has been reviewed by subject matter experts. These reviews have been conducted both by individuals, and aeronautical charting interest groups such as the FAA Government/Industry Aeronautical Charting Forum, Air Transport Association Charting and Data Display Working Group (ATA CDDWG), and Society of Automotive Engineers G-10 Aeronautical Charting Subcommittee. The membership of these professional organizations include terminal instrument procedures experts, commercial air carrier pilots and management, commercial and U.S. Government cartographers and chart manufacturers, and military and general aviation representatives. Several of the critiques offered by these experts have been integrated into the prototype format. In addition to these committee reviews, several in-depth reviews of the charts have been conducted with individual pilots, cartographers, and other subject matter experts regarding human factors problems with IAP chart design (Osborne and Huntley, 1993). This continuous process of expert review and refinement has evolved the prototype format to its current state.

Mangold, Eldredge, and Lauber (1992) conducted an extensive literature review in the areas of human factors, cartography, visual psychophysics, reading, and information formatting. General guidance information was then extracted from these references and organized into a set of design tools a cartographer could use to help make formatting decisions. As changes were recommended during the evolution of the prototype's design, this handbook was used as a reference source to verify that the suggested change did not conflict with the available guidance.

Blomberg, Bishop, and Hamilton (in press) conducted a field study for the Volpe Center Cockpit Human Factors Program to determine the preferences of Part 121 air carrier pilots for alternative IAP chart designs. The prototype format which was originally developed for implementation with NOS IAP charts was adapted for Jeppesen style IAP charts. This adaptation was accomplished by Volpe working in cooperation with ATA CDDWG to produce a prototype format tailored for Part 121 carrier use. Jeppesen also produced a prototype version of their chart. These two prototypes were tested against the current Jeppesen format in an operationally realistic environment.

Pilots were asked to give their opinions on the two prototypes and standard Jeppesen IAP formats after flying one of the prototypes and the current format in a full motion conventional or glass cockpit aircraft simulator. Thirty seven pilots flew the Volpe/ATA prototype and 44 other pilots flew the Jeppesen prototype. All 81 pilots flew the current format as well. Ten other pilots did not fly any charts but were briefed on the formats and asked for their opinions. A total of over 400 approaches were flown at the training centers of four commercial air carriers.

Pilots preferred selected features from both prototypes over the current Jeppesen format. These features were combined to produce the composite prototype shown in Figure 2. As evidenced by this figure, the major features of the original NOS prototype remained intact. When pilots were asked to choose which chart they would buy for their company to use, 90 out of the 91 pilots chose one of two prototypes. Fifty nine per cent of the pilots chose the Volpe/ATA prototype. This number was less than expected because pilots exhibited a strong bias for preferring the prototype they flew with. Even so, while 41% of the pilots who flew with the Jeppesen prototype picked the Volpe/ATA prototype, only 16% of the pilots who flew with the Volpe/ATA prototype crossed over and picked the Jeppesen prototype. The comments indicated that having a chance to use the briefing strip and missed approach icons during simulated flight convinced pilots that these features allowed them to find the information faster. Pilots did not expect any problems in implementing a prototype chart on the flight line.

1.3 PROTOTYPE IAP CHART FORMAT

All of the work described above has contributed to the evolution of a prototype NOS IAP chart format. This design that was originally developed in the laboratory for NOS IAP charts and refined during field testing with Jeppesen IAP charts and subject matter expert reviews is shown in Figure 3. The purpose of the prototype is to improve the speed and accuracy with which pilots locate and comprehend information on IAP charts.

1.3.1 Briefing Strip

These three rows of information are used for preparing for the approach. Each information element is given in the order in which it will be used. In the first and third lines of the strip, the information to be briefed is given in bold type, while the name of the information is shown in regular type. The pilot no longer has to search through the entire chart to assemble this data.

1.3.1.1 - The information required for quick reference is in the top row. The concept of formatting this safety critical information (particularly the first three items) grew out of subject matter expert interviews (Osborne and Huntley, 1993). The first box contains the type, identifier, and frequency of the navaid that serves this approach. The final approach course is given in the second box. The third box contains the final approach fix (FAF) name and the altitude at the FAF. The fourth box shows the touchdown zone elevation (TDZE). If the charted procedure were a non-precision approach to either of two runways, both TDZEs

Not for Navigation

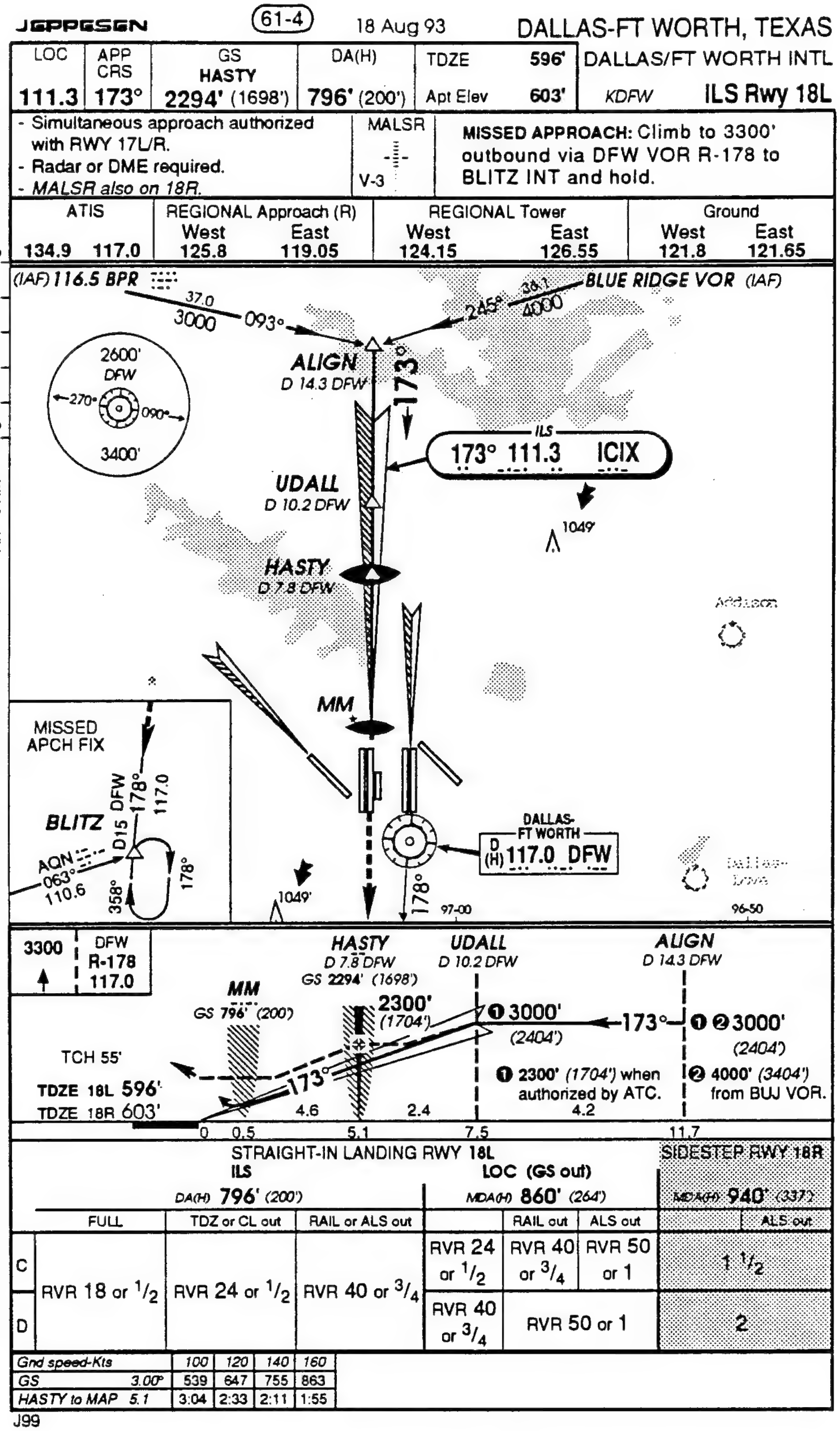

Figure 2. Prototype Volpe/ATA Part 121 IAP Chart for the ILS Approach to Runway 18 Left at Dallas/Fort Worth International Airport

Not for Navigation

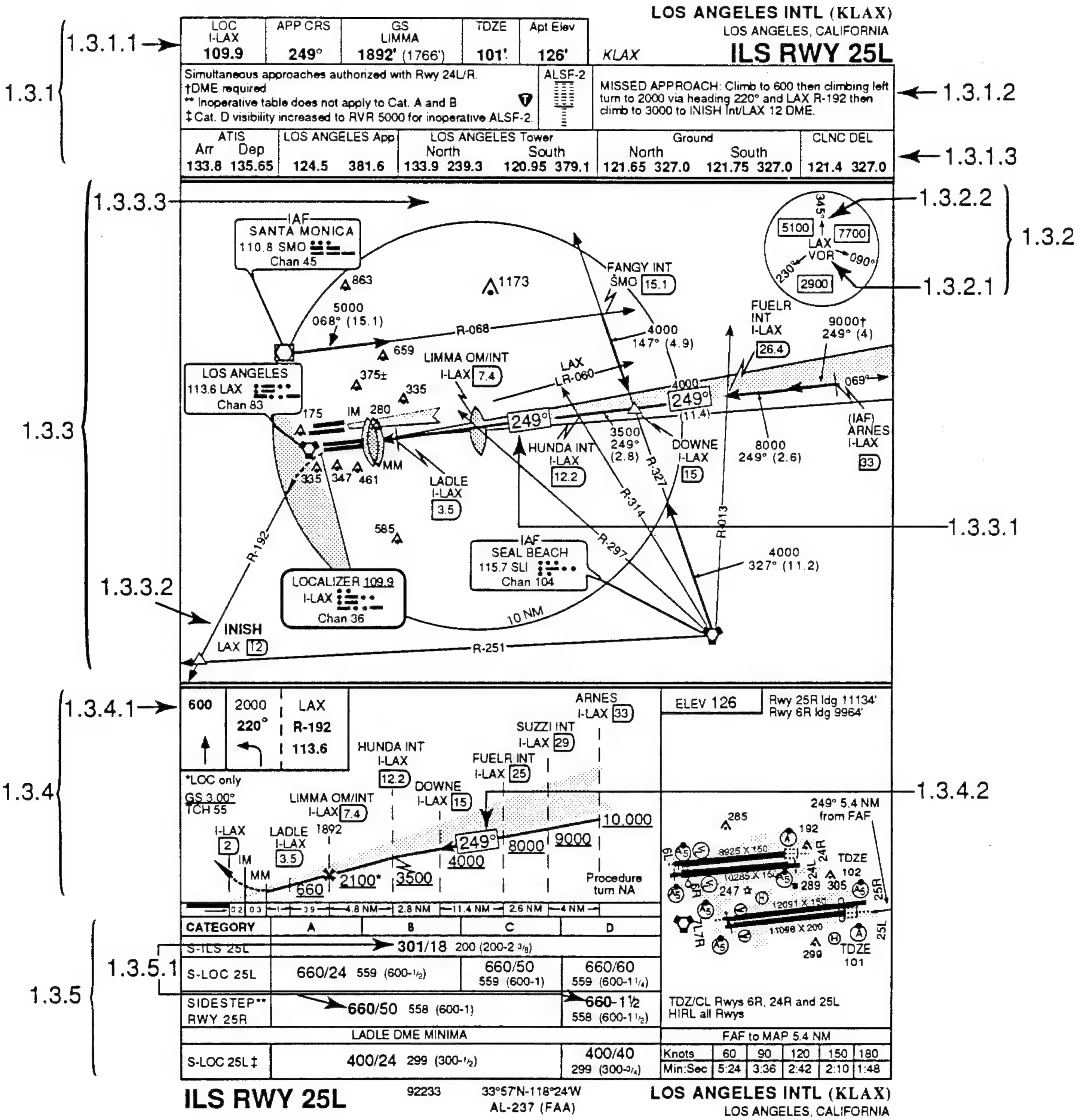

Figure 3. Prototype IAP Chart for the ILS Approach to Runway 25 Left at Los Angeles International Aiport

would be shown, and both would be bolded. The airport elevation is given in the fifth box. To the right of this row, the four-letter ICAO airport identifier is shown in italics.

1.3.1.2 - The second row contains all equipment and procedural notes (navigation notes remain in the profile section), an approach lighting system sketch, and missed approach instructions. If any visual glideslope indicators are present, they are also depicted in the approach lighting system sketch. If a parallel runway has the same lighting system, an italicized note is given in the notes box. Locating all equipment and procedural notes in one location helps pilots to find the notes they are looking for, as well as notice the notes that might previously have been unnoticed in a densely packed plan view. These notes have been moved up to the top of the chart to make them easier to read in poor lighting. The approach lighting sketch was initially recommended by a Part 121 flight crew during a jumpseat interview (Osborne and Huntley, 1993). This sketch received strong support during field testing (Blomberg, Bishop, and Hamilton, in press).

1.3.1.3 - The results of research conducted by Multer, Warner, DiSario, and Huntley (1991) on communication frequency layout are implemented in the third row of the briefing strip. The ATIS and communication frequencies are listed in order of their use and the numbers are always shown under the labels. In order to save space, they are not as large as the numbers listed above. They are made available here for verification, early radio set-up, or in case of blockage of an active communication channel. Both general aviation and air carrier pilots recommended that since the plan view is oriented North-up, any West and East frequencies should be placed on the left and right, respectively (Osborne and Huntley, 1993).

1.3.2 MSA Circle

The MSA circle will float within the plan view to occupy unused space.

1.3.2.1 - The text identification for the reference navigational aid (navaid) is given in the center of the circle (Osborne and Huntley, 1993).

1.3.2.2 - The sectors of the circle are defined by radials rather than bearings, since pilots usually think in terms of radials rather than bearings to the station (Osborne and Huntley, 1993).

1.3.3 Plan View

1.3.3.1 - The approach course number has been boxed to enhance detectability and readability (Multer, Warner, DiSario, and Huntley, 1991).

1.3.3.2 - The name of the missed approach holding fix has been bolded (Mangold, Eldredge, and Lauber, 1992).

1.3.3.3 - The enroute facilities and feeder facilities rings have been removed (Osborne and Huntley, 1993).

1.3.4 Profile View

1.3.4.1 - In the profile view, the "up and out" portion of the missed approach instructions is depicted in icons rather than text. These icons tell the pilot all that is required to get the plane up and out - and this critical information is more easily located than if it were embedded in text. The first altitude and navaid frequency are emphasized by bolding. If there was a heading in the first box, it too would be bolded. Osborne and Huntley (1992) demonstrated that encoding the missed approach instructions in icons allows pilots to comprehend the instructions faster than text instructions.

1.3.4.2 - The approach course number has been boxed here as well (Multer, Warner, DiSario, and Huntley, 1991).

1.3.5 Minimums

1.3.5.1 - Bold type has been used to make the MDAs easier to find and read (Mangold, Eldredge, and Lauber, 1992).

1.4 PRESENT RESEARCH ISSUES

Although individual components of the prototype had been tested in the laboratory, and the format as a whole had been applied to a Jeppesen style IAP chart and field tested, another evaluation was needed to determine the effects of applying the format to an NOS chart. Measurements of the search time required by pilots to find specific information items, as well as the accuracy of their search during actual flight were needed to determine if the prototype format would allow faster and more accurate information retrieval than the current NOS format.

1.5 OBJECTIVE AND HYPOTHESES

The objective of this study was to determine if the prototype IAP chart format would allow pilots to find information faster and more accurately during actual flight. The specific hypotheses were:

- The formatting of the briefing strip would result in faster and more accurate retrieval of the information it contained than the current NOS formatting of that information.
- Iconic missed approach instructions would produce faster and more accurate information retrieval than text instructions.
- Overall, the prototype chart would produce faster and more accurate information retrieval than the NOS chart.
- Pilots would prefer the prototype format to the NOS format.

2. METHOD

2.1 SUBJECTS

Ten licensed pilots rated for flight during instrument flight rules (IFR) conditions participated as subjects in this experiment. Pilots were recruited from a subject pilot database maintained at the Center for Human Factors Research in Transportation at the Volpe Center. Pilots were paid ten dollars per hour of simulator time, and were reimbursed for their travel and lodging expenses.

Eight pilots were male. Pilots' ages ranged from 20 to 70 years, with a median of 34.2 years. Total flight time ranged from 375 to 15000 hours, with a median of 875 hours. Total instrument time ranged from 50 to 1500 hours, with a median of 110 hours. Ten, four, and one pilot had general aviation experience in aircraft categories A, B, and C, respectively. The pilot with 15000 total hours and 1500 instrument hours had military flight experience in categories B, C, and D aircraft, and corporate flight experience in category A aircraft. One pilot had corporate flight experience in category C aircraft.

The mean percentages of time pilots reported using Jeppesen IAP charts and NOS IAP charts were 42% and 58%, respectively. Four pilots reported a preference for Jeppesen IAP charts, five pilots reported a preference for NOS IAP charts, and one pilot expressed no preference.

2.2 APPARATUS

Instrument approach procedure (IAP) charts Each of the approaches were depicted in four charting formats, as shown in Table 1. Each approach was based on an actual approach taken from the U.S. Terminal Procedures charts published by the U.S. National Oceanic and Atmospheric Administration (1994a, 1994b, 1994c, 1994d, 1994e, 1994f).

Gardner Municipal Airport (GDM) was selected as the study site because it has relatively low amounts of traffic during the week, and previous studies have constructed and safely flown prototype Global Positioning System (GPS) approaches at GDM. The GPS overlay approaches were constructed because it was not possible to use actual VOR or NDB approaches for this experiment. It would have been desirable to have had pilots fly actual VOR and NDB approaches. However, GDM and other nearby airports did not have enough of these established instrument approaches. Even if enough of these approaches were available, there would have been an unacceptably high level of overlap for frequencies used for communication and for tuning navigation instruments, and geographic features. Additionally, local pilots would have memorized many of these features, flight paths and frequencies. As a result, non-precision approaches from around the United States were selected for the study. The objective of the selection was primarily to obtain a range of information density in the group of charts.

Table 1.
Instrument Approach Procedure Charts Used in This Experiment

	NOS		Prototype	
	Rwy 18	Rwy 36	Rwy 18	Rwy 36
AVP				
BTV				
COS				
DFW				
FDK				
MFR				
RNO				
SAT				

For each chart taken from the U.S. Terminal Procedures charts, the distance and bearing of each fix (initial, final, and other fixes) from that particular runway end were calculated. The geometric relationship between those fixes was the flight path of that approach procedure. The latitude and longitude of the runway ends at GDM were known. To replicate the geometry of an approach, the GDM runway end was used as a starting point and the distance and bearing of each fix was plotted from that point.

The charted procedures were actually flown in this experiment, and because of prevailing winds, some pilots flew some or all of their approaches to runway 18 at GDM, and some or all of their approaches to runway 36. Each pilot was assigned his/her specific order of approaches according to a counterbalancing schedule. Because of the method used to construct the GPS approaches, the landing direction was irrelevant to the counterbalancing schedule. Each GPS procedure constructed for an approach to one runway end (e.g., AVP Rwy 18) was rotated approximately 180° to construct the GPS procedure for the approach to the opposite runway end (e.g., AVP Rwy 36). Therefore, for any approach (AVP, BTV, etc.) the geometry of the procedures to both runway ends were identical.

The charts were drawn using Adobe Illustrator 5.5 installed on an Apple MacIntosh IIci computer, and were printed with a Hewlett-Packard Laser Jet IIIsi with 400 dots per inch emulated resolution.

Frasca 242 flight simulator This twin-engine instrument flight simulator is a fixed-base training device which has been reconfigured and instrumented for data collection. There is no outside visual display. The specific aircraft model used for this study was designed to approximate the flight characteristics of a Beechcraft Baron BE55. A depiction of the

instrument panel layout is given in Figure 4. Both in the simulator and in the airplane, pilots chose between a Thunderhead training visor (instrument hood) or Foggles.

Simulated GPS receiver A simulated GPS receiver in the Frasca displayed navigation information on the liquid crystal display (LCD) panel. The display showed the previous waypoint, the waypoint being flown to, the distance to that waypoint, and the bearing to that waypoint (see Figure 5). The simulated receiver also drove the course deviation indicator (CDI) on the horizontal situation indicator (HSI). Needle sensitivity was set to 3/10 nm full scale.

Beechcraft Baron BE55 This twin-engine four-seat aircraft was selected because in single pilot operations it creates a relatively high level of pilot workload during terminal area procedures (Huntley, Turner, and Palmer, 1993). Figure 6 depicts the instrument panel layout. The aircraft was based at a fixed base operator's facilities at Laurence G. Hanscom Field (BED). As a safety precaution, both the pilot and the safety pilot had a complete set of current NOS IAP approach charts available to them at all times.

Garmin 155 TSO GPS receiver Course guidance in the Baron was provided by a Garmin GPS receiver mounted in the radio stack in front of the safety pilot. The receiver's display showed the previous waypoint, the waypoint being flown to, the distance to that waypoint, a CDI, the ground speed, the bearing to that waypoint, and the aircraft track over the ground (see Figure 7). The receiver also drove the CDI on the HSI. Needle sensitivity was set to 3/10 nm full scale.

Liquid Crystal Light Shutter One 6 x 9 inch Taliq Corporation liquid crystal light shutter was mounted between two plates of .15 inch thick Lexan plexiglass in a 6.4 x 9.5 x 0.4 inch aluminum frame (see Figure 8). The frame was open on one side to allow insertion and extraction of the charts. This .05 inch thick light shutter was a polymer encapsulated numatic curvilinear aligned phase device whose liquid crystal molecules were not aligned in parallel. This non-parallel alignment resulted in the scattering of light which rendered the device translucent but not clear. When a 90 volt 6.67 mA AC electric field was applied across the device, the molecules aligned and the shutter cleared in 10 msec. When the electric field was removed, the shutter returned to the masked condition in 30 msec.

All charts were mounted on a 6 x 8.5 inch piece of cardboard. The shutter unit was sized to accept this cardboard mounting when the safety pilot dropped it into the housing behind the shutter. Charts were held in place with a Velcro strap placed across the housing's open side.

The shutter was in its masked state until activated to its clear state by the pilot. A push-to-talk switch was attached to the pilot's yoke with Velcro straps. This toggle switch was used to operate the shutter. The switch was spring loaded and set toggled to the "off" position, which was the "masked" state for the shutter. The toggle had be activated and held active to clear the shutter. When the toggle was released, the shutter returned to its masked state. A 10 Hertz sampling rate was used by the Gateway 2000 Handbook 486 laptop computer to detect whether the switch was activated.

1. Magnetic compass
2. GPS annunciator panel
3. DME display
4. Intercom control (PM 1000)
5. Airspeed indicator
6. Attitude indicator (King Flight Command Indicator)
7. Pressure altimeter
8. Dual manifold pressure indicator
9. Clock
10. Automatic direction finder (dual needle RMI)
11. Turn coordinator
12. Horizontal situation Indicator (King PNI)
13. Vertical velocity indicator
14. Dual tachometer
15. VHF navigation dual needle ILS CDI
16. LCD display (research)
17. VHF navigation dual needle ILS CDI
18. Fuel flow indicators
19. Flat panel display (research)
20. Selector button bar (research)
21. Autopilot (King KFC-150)
22. GPS receiver (II Morrow Apollo 2001NMS)
23. Marker beacon/audio switch (King KMA24)
24. VHF NAVCOM 1 transceiver
25. VHF NAVCOM 2 transceiver
26. Automatic direction finder receiver
27. Mode C radar transponder
28. Distance measuring equipment
29. Fuel quantity indicators
30. Fuel pressure indicators
31. Oil pressure indicators
32. Oil temperature indicators
33. Cylinder head temperature indicators
34. Electrical load meters
35. Hourmeter
36. Microphone and headphone jacks
37. Master switch
38. Left generator switch
39. Right generator switch
40. Avionics master switch
41. Left engine left magneto switch
42. Left engine right magneto switch
43. Left engine primer button
44. Right engine primer button
45. Starter switch
46. Right engine left magneto switch
47. Right engine right magneto switch
48. Left landing light switch
49. Right landing light switch
50. Navigation position light switch
51. Anti-collision light switch
52. Pitot heat switch
53. Left fuel boost pump switch
54. Right fuel boost pump switch
55. Rotating beacon switch
56. Pneumatic system pressure indicators
57. Landing gear position indicator lights
58. Landing gear control lever
59. Landing gear warning horn silencer button
60. Parking brake control knob
61. Flat panel display intensity rheostat
62. Throttle controls
63. Propeller controls
64. Mixture controls
65. Carburetor heat controls
66. Throttle quadrant friction adjustment knob

Cockpit Layout

FRASCA 242
Research Flight Simulator
Cockpit Human Factors Program
Volpe National Transportation Systems Center

67. Fuel tank selector valves
68. Cowl flap controls
69. Wing flaps % position indicator
70. Wing flaps control lever
71. Elevator trim wheel and position indicator
72. Aileron trim control and position indicator
73. Rudder trim control and position indicator

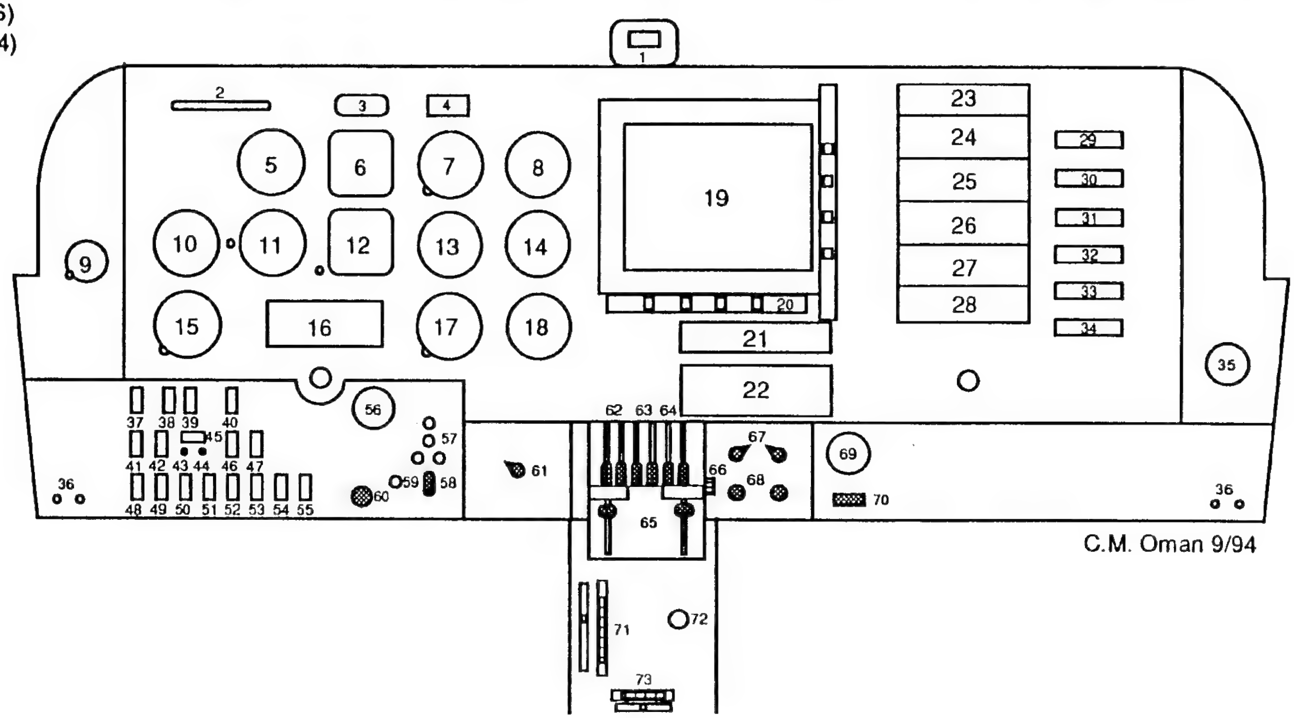

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Figure 4. Frasca 242 Flight Simulator Cockpit Layout

FIPA --> KATY

DTW 4 nm

BRG 003 deg

Figure 5. Simulated GPS receiver display showed the previous waypoint (FIPA), the waypoint being flown to (KATY), the distance to that waypoint (4 nm), and the bearing to that waypoint (003°)

Laptop computer A Gateway 2000 Handbook 486 computer controlled both the data collection software and hardware interface for the light shutter. The experimenter's graphic interface was written in Visual Basic.

2.3 PROCEDURE

Table 2 delineates the series of activities each pilot stepped through. As shown in this table, pilots participated for two days. The first day consisted of training in the Frasca 242 simulator. The purpose of this first day was to give the pilots experience in using the prototype chart format, flying with guidance from a GPS receiver, and having someone ask them a series of questions while flying an approach. Data collection during actual flight occurred on the second day. Both days were composed of a morning session and an afternoon session. In each session, pilots were exposed to only one chart format (NOS or prototype). Pilots were randomly assigned to be trained first on either the NOS or prototype format charts. All pilots received training for and flew with both chart formats.

The simulator day preceded the airplane day by no more than 7 days. However, on the airplane day, pilots were not expected to recall all the experimental procedures and differences between the chart formats. Therefore, the experimenter refamiliarized pilots with the procedures and formats before pilots began the airplane day's practice trials. Pilots were told that each session (morning and afternoon) consisted of a practice trial followed by four data collection trials.

Simulator Day: Questionnaires and Chart Format Training Pilots were seated at a table and read an informed consent form summarizing the purpose and general procedures of the experiment (see Appendix A). They then completed a questionnaire concerning their flight experience and preferences for IAP chart manufacturers (see Appendix B). Pilots then read a description of the flight procedures (see Appendix C), and the experimenter answered any procedural questions.

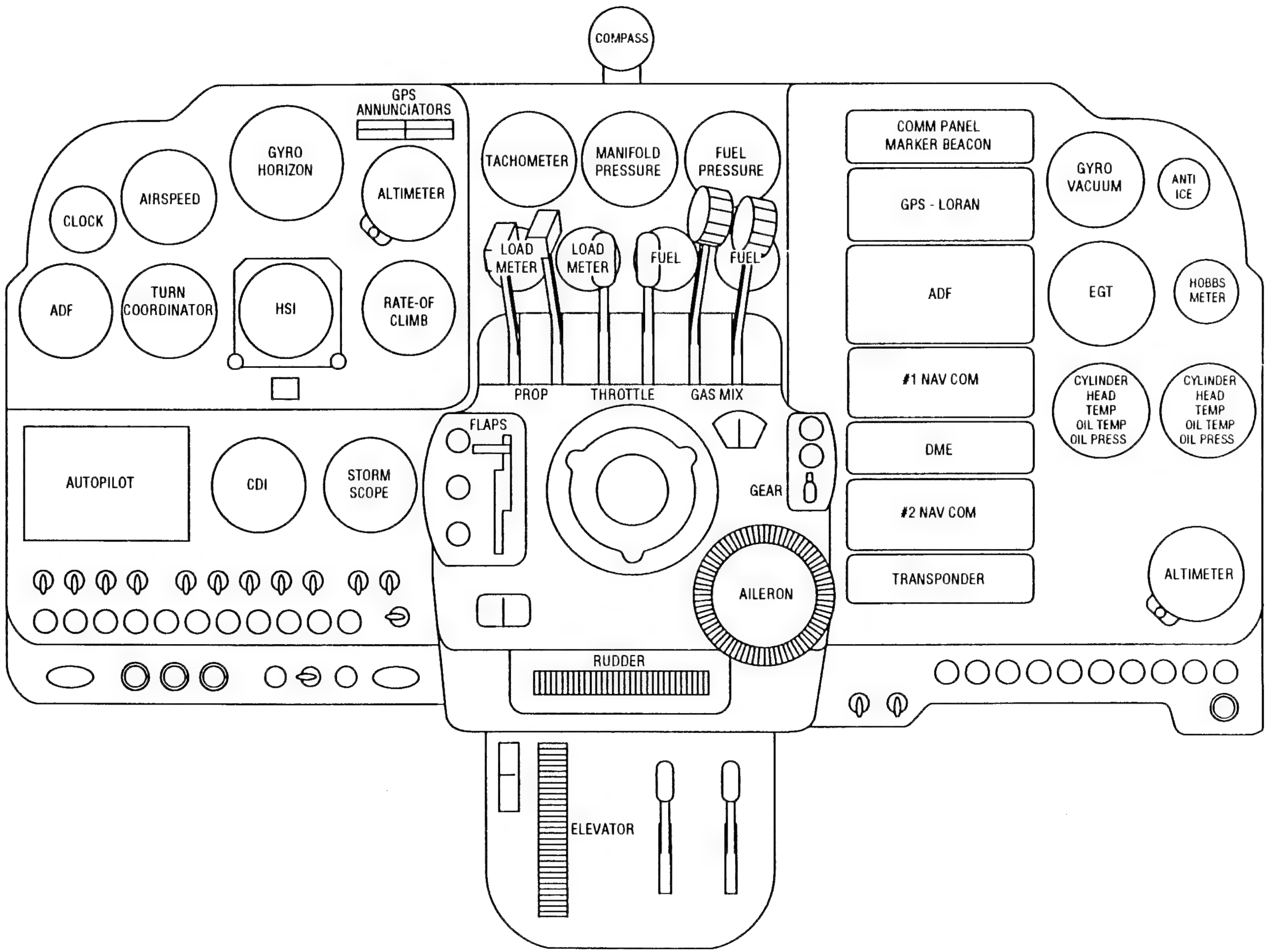


Figure 6. Beechcraft Baron BE55 Cockpit Layout

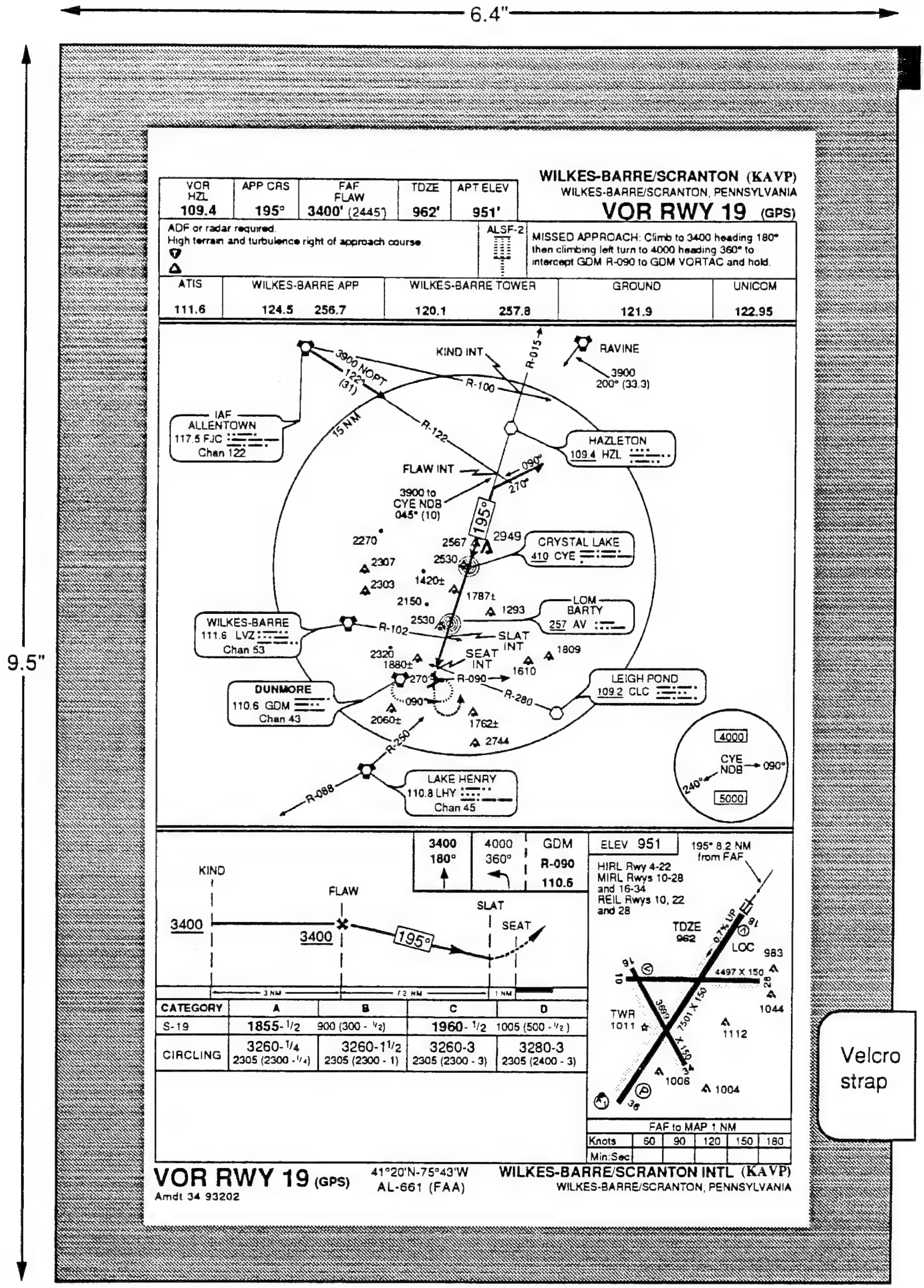
FIPA --> KATY gs: 120^{KT}
dis 4.00^{nm} brg: 003°
+ + + + + ↑ + + + + + trk 003°

Figure 7. Garmin GPS 155 receiver display showed the previous waypoint (FIPA), the waypoint being flown to (KATY), the distance to that waypoint (4 nm), a CDI, the ground speed (120 kt), the bearing to that waypoint (003°), and the aircraft track over the ground (003°)

Then the pilot was seated in the left seat of the simulator, and had an opportunity to become familiar with the instrument suite. Unlike the airplane session, no safety pilot was present in the simulator. When the experimenter was satisfied that the pilot understood the instrumentation and avionics layout, the pilot was allowed to fly for 15 minutes, and was instructed to fly whatever maneuvers he/she wished to get familiar with the handling and flight characteristics of the simulator. During this time the pilot was encouraged to ask questions. At the conclusion of this 15 minute period, the experimenter brought the pilot out of the simulator and back to the table for chart format training.

<u>Simulator Day Training (Airplane Day Refamiliarization): NOS Format Charts</u> The experimenter began by showing pilots an NOS format IAP chart of a GPS overlay VOR approach to runway 25R at Los Angeles International Airport (LAX). Both training charts are shown in Appendix D. The experimenter reviewed the information elements (e.g., communication frequencies, missed approach instructions, etc.) and their locations throughout the chart, referring to the guide shown in Appendix E to ensure that each section of the chart was reviewed. Pilots were allowed as much time as they wished to review the chart by themselves and were encouraged to ask questions. After subjects indicated that they understood the format, the simulator or airplane activities began.

<u>Simulator Day Training (Airplane Day Refamiliarization): Prototype Format Charts</u> Unlike any of the other information on the prototype versions of the IAP charts, iconic missed approach instructions were a new concept for the pilots. Training in interpreting iconic missed approach instructions began with pilots studying the examples shown in Appendix F. These examples were composed of similar kinds of instructions pilots would encounter during the experiment. Pilots had as much time as they wished to study the examples and were encouraged to ask questions. When they completed studying the examples, the experimenter gave pilots the self test shown in Appendix G. After completing the self-test on their own, the experimenter reviewed the items in a pseudorandom order, and any errors were corrected by the experimenter. None of the pilots misinterpreted the icons. Pilots were required to demonstrate 100% accuracy in order to proceed to the prototype format training. All pilots met this criterion.



Note: Illustration not actual size.

Figure 8. Physical Dimensions of the Liquid Crystal Light Shutter

Table 2.
Sequence of Activities and Hypothetical Counterbalanced
Order of Experimental Conditions

Day 1: Training in the simulator	
Informed Consent Form	
Flight Experience and Chart Usage Questionnaire	
Description of flight procedures	
Familiarization with simulator operation	
Training: NOS format charts	
Practice trial with NOS format chart	missed approach
Data trial with NOS format chart	missed approach
Data trial with NOS format chart	land - subject gets out of sim for a break
Data trial with NOS format chart	missed approach
Data trial with NOS format chart	missed approach
Lunch	
Training: prototype format charts	
Practice trial with prototype format chart	missed approach
Data trial with prototype format chart	missed approach
Data trial with prototype format chart	land - subject gets out of sim for a break
Data trial with prototype format chart	missed approach
Data trial with prototype format chart	missed approach

Table 2 (cont.)
Sequence of Activities and Hypothetical Counterbalanced
Order of Experimental Conditions

Day 2: Airplane	
Description of flight procedures	
Familiarization with Baron BE 55	
Training (refamiliarization): NOS format charts	
Practice trial with NOS format chart	missed approach
Data trial with NOS format chart	missed approach
Data trial with NOS format chart	land - subject gets out of airplane for a break
Data trial with NOS format chart	missed approach
Data trial with NOS format chart	missed approach
Lunch	
Training (refamiliarization): prototype format charts	
Practice trial with prototype format chart	missed approach
Data trial with prototype format chart	missed approach
Data trial with prototype format chart	land - subject gets out of airplane for a break
Data trial with prototype format chart	missed approach
Data trial with prototype format chart	missed approach

The experimenter then showed pilots the prototype version of the GPS overlay VOR approach to runway 25R at LAX shown in Appendix D. Following the guide shown in Appendix E, the experimenter verbally explained the types and locations of information elements throughout the chart. Pilots were allowed as much time as they wished to review the charts by themselves and were encouraged to ask questions.

Airplane or Simulator Days: Flying the Charted Approaches GPS approaches can be constructed and loaded as flight plans in most GPS receivers' databases. If a pilot wished to

fly a particular approach, that flight plan could be called up and activated. The receiver would then provide course guidance based on the aircraft's position relative to the waypoints specified in the flight plan. Therefore, the number of GPS approaches possible for any runway are limited only by the receiver's memory capacity and regulations imposed on the construction of terminal instrument procedures. As long as the charts depict a profile for approaches to the runway at GDM (and a safety pilot is present), any chart used to approach and land at GDM can appear to be drawn for any airport with a runway having a similar heading. Since it was possible to provide actual flight guidance when pilots flew GPS approaches which were created specifically for the study, the chart formats were evaluated as the approaches they depicted were being flown.

By having pilots fly the approaches, the ability of pilots to retrieve information from the chart formats could be tested in the operational environment in which the charts are actually used, under realistic levels of pilot workload. The pilots also used the charts to obtain heading, altitude, MDA, and missed approach information even when they were not being asked questions by the experimenter.

Simulator Day: Preparation for Practice Trials When the chart format training was completed, the experimenter brought the pilot back to the left seat of the simulator. Although the simulator had no outside visual display, pilots were required to wear their choice of foggles or an instrument hood to more accurately simulate conditions during the actual flight portion of the study. Although no light shutter data were collected in the simulator session, pilots were instructed to "Fly to the same standards you trained to for your instrument practical test. Fly each approach at 120 knots ± 10 knots, and maintain the altitudes ±100 feet."

Pilots were informed that course guidance would be provided by a simulated GPS receiver. The simulated receiver's display showed the waypoint you were flying to, the distance to that waypoint, and the bearing to that waypoint (see Figure 5). This display was presented on an LCD panel in the center of the instrument suite. The receiver also drove the course deviation indicator (CDI) on the horizontal situation indicator (HSI). Needle sensitivity was set to 3/10 nm full scale.

Pilots were told that after they crossed the MAP, they were then to disregard the GPS course guidance and use as their source of guidance the NAV 2 OBS which had been tuned to the GARDNER VOR (110.6). In every non-landing trial, pilots had to intercept a different radial leading to the missed approach holding fix. This was done in order to give pilots ample opportunity to gain experience in using the iconic missed approach instructions.

Airplane Day: Preparation for Practice Trials The pilot was seated at a table and read a description of the flight procedures (see Appendix C), and the safety pilot and experimenter answered any procedural questions the pilot had. The pilot was then seated in the left seat of the airplane. There are variations in instrumentation and avionics among different models of the Beechcraft Baron BE-55. Therefore, the pilot was verbally briefed by the safety pilot on the aircraft's equipment before the engines were started. Pilots were instructed to immediately surrender control of the aircraft to the safety pilot at any time the safety pilot said "I've got it."

The experimenter then introduced the light shutter to the pilot and referred to the guide shown in Appendix H when explaining the operation of the shutter. The pilot had an opportunity to become familiar with operating the shutter, and the experimenter emphasized that the chart should be unmasked only when the pilot wished to view it, and to keep viewing time to a minimum.

The pilot and safety pilot were seated in the left and right seats, respectively. The safety pilot was responsible for monitoring the safety of the flight. The experimenter was seated behind the safety pilot, and was responsible for handing charts to the pilot in the proper order from approach to approach, asking the pilot questions and entering data into a laptop computer, and extracting and inserting charts into the shutter.

When the safety pilot was satisfied that the pilot understood the differences in instrumentation and avionics, and the pilot indicated readiness to begin, the flight to GDM began. The pilot took off from Hanscom Field (BED). After departure from the traffic pattern at BED the pilot donned his/her choice of an instrument hood or foggles, and the safety pilot gave vectors to GDM.

Pilots were informed that course guidance would be provided by the Garmin GPS 155 TSO receiver mounted in the radio stack in front of the safety pilot, and that the safety pilot would be responsible for operating the receiver. The receiver's display showed the previous waypoint, the waypoint being flown to, the distance to that waypoint, a course deviation indicator (CDI), the ground speed, the bearing to that waypoint, and the aircraft track over the ground (see Figure 7). The receiver also drove the CDI on the horizontal situation indicator (HSI). Needle sensitivity was set to 3/10 nm full scale. Pilots were told that after they crossed the MAP, they were then to disregard the GPS course guidance and use as their source of guidance the NAV 2 OBS which had been tuned to the GARDNER VOR (110.6).

Airplane or Simulator Day: Practice Trials and Data Collection The procedures for conducting practice trials and data collection were the same for the simulator and airplane except that the light shutter was not used in the simulator. The pilot had an opportunity to ask the experimenter questions throughout the practice trials. The chart format was either NOS or prototype, depending upon the counterbalanced order for that pilot.

To begin the first practice trial, the experimenter inserted a chart into the shutter. All switch activations were recorded by the laptop computer software, and any activations during this process were recognized as calibration checks during post-flight data analyses. These analyses employed a set of logic operations on the time stamped data to make accurate determinations as to which toggle activations were in response to a question, which activations were due to the pilot independently checking the chart for his/her own reasons, and which activations should be totally ignored such as calibration checks.

At this point in the approach, the safety pilot was giving vectors to the pilot. The safety pilot then informed the pilot and the experimenter that "I am activating the approach," and activated the appropriate flight plan (approach procedure) in the GPS receiver. That approach would have been the same as the approach which was depicted on the pilot's chart. When an

approach was activated in the GPS receiver, the unit provided the pilot with distance and bearing from the aircraft to the first leg of the approach.

The experimenter then asked the pilot if he/she was ready to begin their review of the approach. If the pilot indicated that he/she was ready, the experimenter would hand the shutter to the pilot, as shown in Figure 9. When the experimenter gave the shutter to the pilot, the experimenter pressed the *recording* function key (as illustrated in Figure 10), and instructed the pilot not to look at the chart until he/she was asked the first (quick reference) question. (To begin each trial during the simulator day, the experimenter would place the chart face down on the right seat, and tell the pilot not to look at it until it was time to answer the quick reference question.)

The experimenter then pressed a key to bring the quick reference question and correct answer on the laptop computer screen. This key press defined the beginning of the quick reference question period. The experimenter then asked the pilot the quick reference question which was always the same - "What is the frequency of the VOR [or NDB] that serves this approach, the final approach course, and the altitude of the final approach fix?"

The pilot toggled "clear" before answering. The pilot might have held the toggle "clear" or toggled "clear" and release ("mask") several times while looking for the answer. The laptop computer software recorded the times for each switch activation and release (two time stamps defined each look at the chart). The pilot's answer was recorded as correct or incorrect by the experimenter pressing the appropriate key. That key press defined the end of the quick reference question period and the beginning of the review period. The experimenter then told the pilot to begin his/her review of the approach. The pilot reviewed the approach the way he/she normally would, without interruption from the safety pilot or experimenter.

The pilot told the experimenter when he/she had completed the review. The experimenter then asked the pilot "Are you ready to begin the question and answer session?" If the pilot indicated that he/she was ready, the experimenter pressed another key which displayed the next question with its accompanying correct answer. The laptop's software randomly chose the next question from the 16 questions shown in Table 3. This key press defined the end of the review period.

The pilot might or might not have toggled "clear" before answering. If the pilot remembered the answer from the review, he/she might have recited it from memory. The pilot's answer was recorded as correct or incorrect by the experimenter pressing the appropriate key. That key press defined the end of the question 2 period. The experimenter then pressed a key to ask for the next question. Each question addressed an information element whose appearance and/or formatting had been changed on the prototype chart.

This procedure was repeated for each of the remaining questions. While enroute to the IAF, eight questions were asked; from the IAF to the FAF, five questions; and from the FAF to the missed approach point (MAP), four questions were asked.

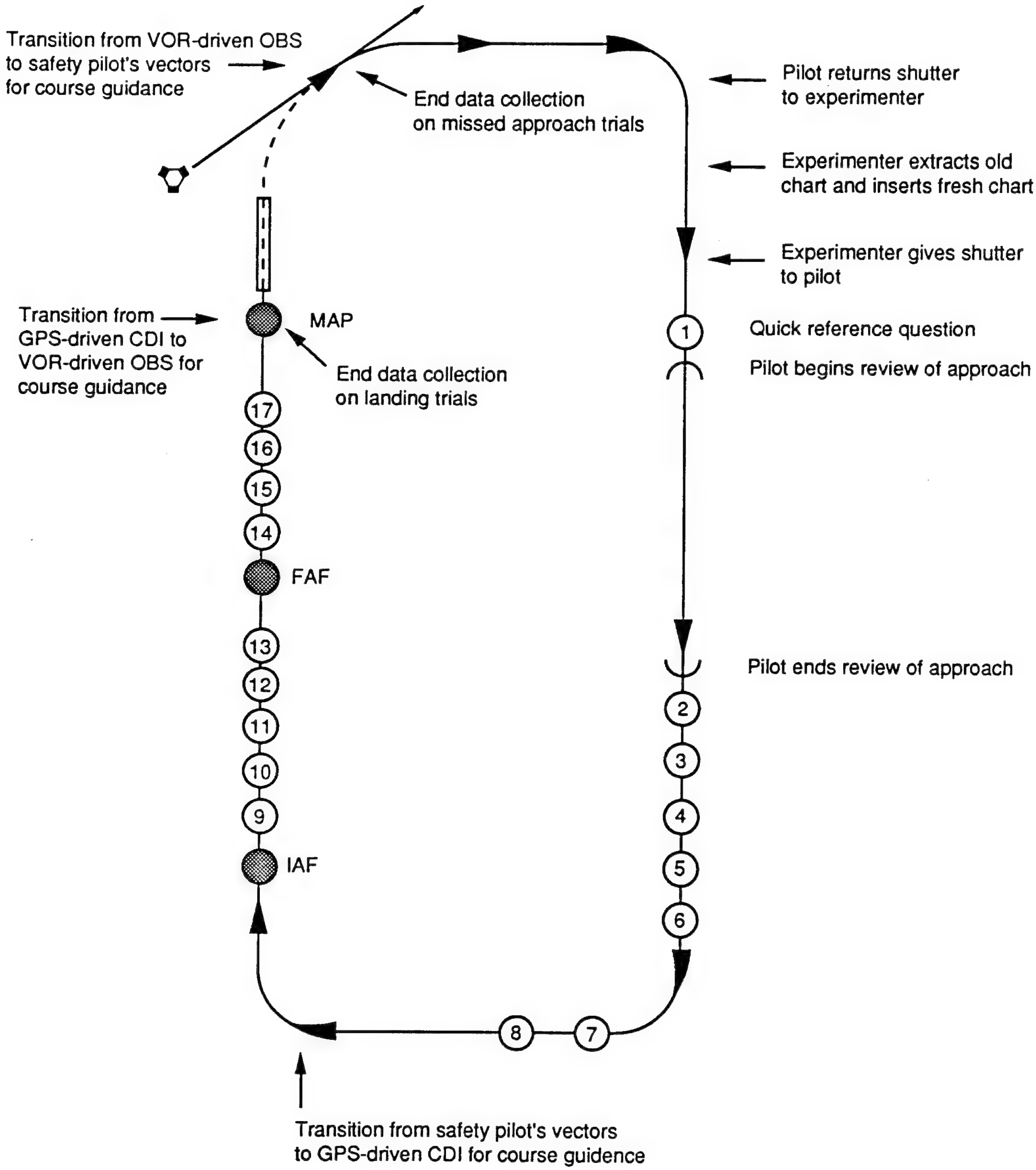


Figure 9. Sequence of Pilot, Safety Pilot, and Experimenter Activities During an Approach Trial

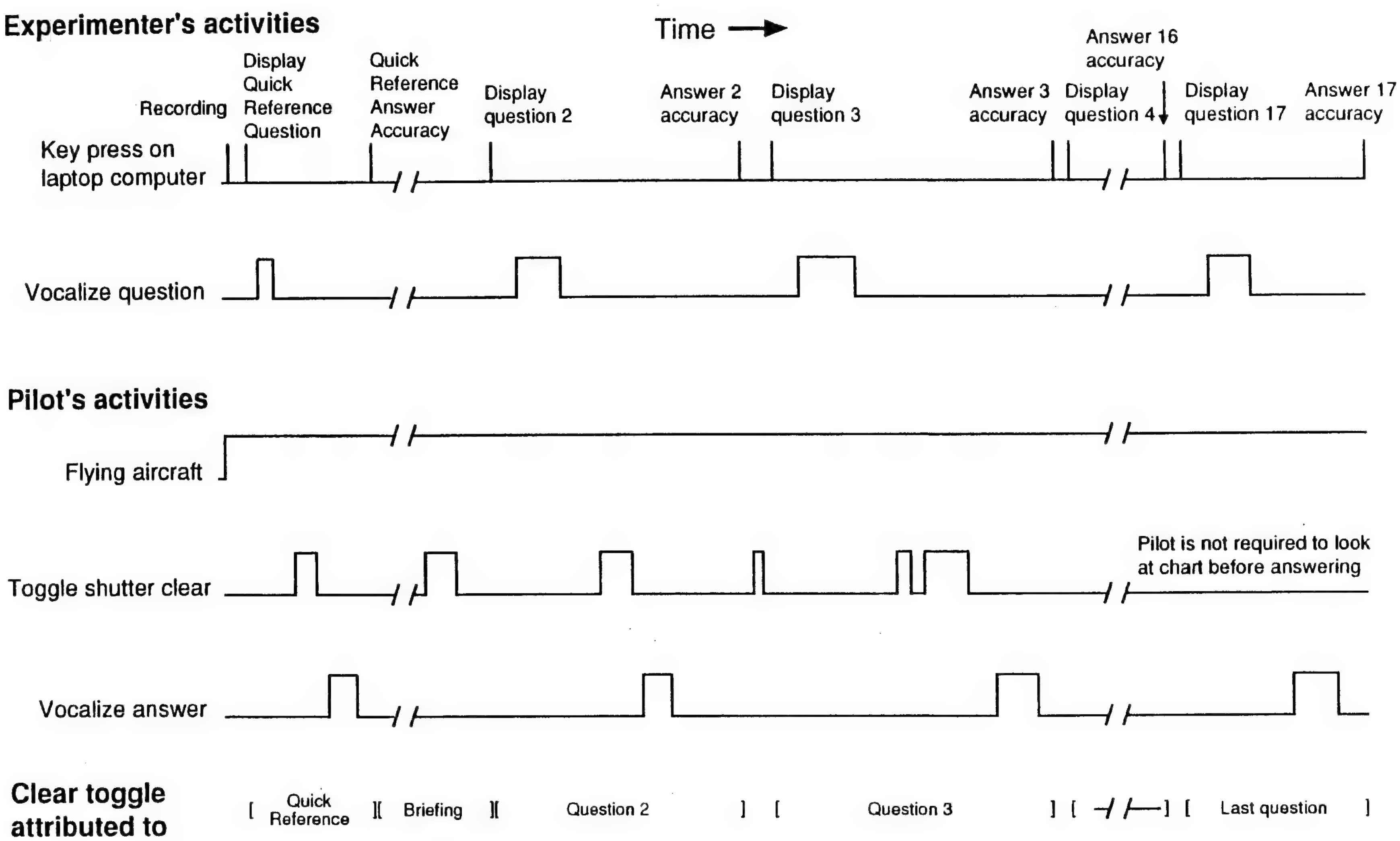


Figure 10. Illustration of How Search Time and Accuracy Data Were Obtained

Table 3.
Approach Test Questions

What is the frequency of the [VOR or NDB]* that serves this approach?
What is the final approach course heading?
What is the correct altitude at the final approach fix?
What is the touchdown zone elevation?
What is the airport elevation?
(A question on the notes specific to that chart.)
What is the approach lighting configuration type?
In the missed approach procedures, what is the [first or second heading or first or second altitude]?
What is the name of the missed approach holding fix?
What is the [ATIS or AWOS-3] frequency?
What is the [approach or UNICOM] frequency?
What is the tower frequency?
What is the [ground or clearance delivery] frequency?
Approaching the airport from the [N, NE, E, SE, S, SW, W, NW] what is the MSA?
Which identifier and type of facility is the MSA circle based on?
What is the minimum descent altitude?
* One of the items shown in brackets was chosen for any one chart.

Pilots were instructed to be prepared to land or fly the missed approach procedure, based on the safety pilot's directions. If they were not specifically told to land by the safety pilot immediately prior to reaching the MAP, they would fly the missed approach procedure shown on the chart. If the pilot was instructed to land, the experimenter pressed the *stop recording* key when the safety pilot told the pilot to land. This key press ended data recording and marked the end of the trial. At that point, the pilot passed the shutter back to the experimenter as a safety precaution. If the pilot was not instructed to land, the experimenter continued to record data until the aircraft intercepted the radial enroute to the missed approach holding fix.

The first practice trial was followed by two data collection trials. The pilot was told to land during the second data trial, and had a 10 minute break during which he/she was required to step out of the airplane (or simulator). Two more data collection trials were then flown before lunch. Immediately following lunch, the experimenter trained/refamiliarized the pilot on the chart format which was not flown in the morning. In the example shown in Table 2, that chart format would have been the prototype format. The training was completed according to the procedures described previously. After successfully completing training, the same sequence of one practice and four data trials was conducted. For each subject, the approaches that were used for the data collection trials in the morning session were not used in the afternoon data collection trials. For each subject, the order of exposure to all independent variables was identical between the simulator and airplane sessions. Combinations such as Morning/NOS and Morning/prototype were counterbalanced between subjects.

Airplane Day: Subjective Assessments After returning to BED, the experimenter and pilot met in a conference room at the fixed base operator. The experimenter used the LAX charts shown during training to conduct the subjective assessments. After handing the NOS LAX chart and the prototype LAX chart to the pilot, the experimenter asked "Which chart did you prefer for answering the first question (frequency of the VOR, approach course, altitude at the final approach fix) - the NOS, the prototype, or no preference?" The experimenter asked for the reasons why one format was preferred over the other, or why there was no preference, and recorded those comments. The experimenter then asked "Which chart did you prefer for reviewing the approach - the NOS, the prototype, or no preference?" The next question was "Which chart did you prefer for executing the approach - the NOS, the prototype, or no preference?" The experimenter then asked "Which chart did you prefer for executing the missed approach procedures - the NOS, the prototype, or no preference?" Finally, the experimenter asked "What features of the prototype chart did you *not* use?"

2.4 PERFORMANCE MEASURES

The objective of the prototype format was to increase pilots' speed and accuracy of information retrieval from approach charts. Therefore, the performance measures focused on these dependent variables. Search time was obtained by measuring the elapsed time between a depression of the shutter toggle followed by a release. The accuracy of answers to each of the 17 questions was measured as either correct (1) or incorrect (0).

Determining Search Time for Each Question As shown in Figure 10, the experimenter pressed a key to display a question and its answer on the laptop computer screen. This key press defined the beginning of that question's period. Any toggle *clear* which occurred after the experimenter pressed that key and before pressing the key to record the accuracy of the pilot's response was recorded as being in response to that question. The pilot was not required to toggle "clear" before answering, since if he/she remembered the answer from a previous look they would not need to look again for that answer. The experimenter's key press denoting accuracy defined the end of that question's time period.

Determining Search Time for Reviewing the Approach Pilots were allowed to clear the shutter at any time. A question was not required. The pilot might have decided that it was

necessary or desirable to examine the chart at that particular moment. Although these shutter activations could occur all along the approach, only those occurring during the period when the pilot was reviewing the approach were of interest.

As shown in Figure 9, the entire review session which occurred prior to the IAF consisted of one or a series of these shutter activations. The search time for the review period was defined as the total elapsed time the shutter was clear during this period. This period was defined in the data as beginning with the experimenter's key press to record the accuracy of the answer to the quick reference question, and ending with the experimenter's key press to call for the second question. No questions were asked during the pilot's review of the approach.

Subjective Assessments Both quantitative and qualitative data were obtained in this portion of the study. For the quick reference question and for each approach phase (review, execution, and missed approach), whether the pilot preferred a chart (1) or had no preference (0) was recorded, as well as the reasons for that response.

For the open-ended questions regarding the features of the prototype chart which pilots did not use and if they had any other comments, the comments were recorded and frequency counts of the comments' topics were computed.

Optimizing Data Collection Accuracy: Standbys and Lock-outs Experience gained from pretesting the experimental procedures showed that sometimes pilots need to access the chart for information that has nothing to do with the question currently being asked. For example, the experimenter might press a key to bring up the next question, which might be "What is the approach frequency?", while at that particular moment the pilot might be preoccupied with trying to find the minimum descent altitude. The result would be that toggle *clears* for the minimum descent altitude would get combined with the toggle clears for the approach frequency and artificially inflate the search time needed to answer the approach frequency question.

Although randomizing the order in which questions were asked rendered this source of noise unsystematic, the sensitivity of the performance measure was reduced. This problem was solved by creating a *standby* option for the pilot and experimenter. The pilot was instructed to say "Standby." if the experimenter asked a question and the pilot was preoccupied with another chart item or any other flying task. With this procedure in place, if the experimenter pressed a key to bring up the next question such as "What is the approach frequency?" while at that particular moment the pilot was preoccupied with trying to find the minimum descent altitude, the pilot would simply have said "Standby." and the experimenter would have recorded a comment in the data base which would be found during post-flight data analyses. The toggles would then be corrected. When the pilot was ready to resume, he/she would have said "Ready." or asked the experimenter to repeat the question. Again, the experimenter would enter another comment in the data file so that the upcoming toggles would be correctly attributed. The experimenter would then repeat the question.

Another safeguard to improve the accuracy of determining the cause of toggles was controlled by the laptop computer's software. When the pilot toggled the shutter *clear*, the experimenter was locked out from pressing a key to display the next question. As soon as the pilot released

the button and the shutter returned to its default masked state, the experimenter was again able to display the next question screen with a key press. Pilots were never locked out from clearing the shutter, regardless of what the experimenter was doing.

2.5 EXPERIMENTAL DESIGN

The main effect of chart format (NOS or prototype) was the main effect of primary interest. Preliminary data analyses uncovered another main effect, which was the order in which pilots flew the chart formats. This main effect for format order had two conditions: NOS-then-prototype, and prototype-then-NOS.

Table 4 shows the experimental design. The within-subjects independent variable was chart format. The between-subjects independent variable was format order. A series of *t* tests (Kirk, 1982) were conducted on the search time and accuracy data for the two main effects and their interaction.

Table 4.
Experimental Design

NOS then Prototype Format Order		
	NOS	Prototype
$Pilot_2$		
$Pilot_4$		
$Pilot_6$		
$Pilot_8$		
$Pilot_{10}$		

Prototype then NOS format Order		
	Prototype	NOS
$Pilot_1$		
$Pilot_3$		
$Pilot_5$		
$Pilot_7$		
$Pilot_9$		

3. RESULTS

3.1 DATA ANALYSIS PROCEDURE

A series of t tests (Kirk, 1982) were conducted on the search time and accuracy data. Two main effects and their interaction were tested for statistical significance. The main effect of chart format (NOS or prototype) was the main effect of primary interest. Preliminary data analyses uncovered another main effect, which was the order in which pilots flew the chart formats. This main effect for format order had two conditions: NOS-then-prototype, and prototype-then-NOS. The nature of the format order effect is addressed in the Discussion section of this report.

The first t test conducted for any dependent variable (e.g., the mean search time required to answer the quick reference question) was conducted on the interaction of chart format and format order. Within each format order, a score was obtained by computing the mean difference between the search time for that variable for NOS charts and the search time for that variable for prototype charts. The t test then was used to determine if the difference score for one format order differed significantly ($p < .05$) from the difference score for the other format order.

If the interaction were significant, then the effect for chart format would have been shown to be dependent upon the format order condition. In other words, in order to analyze the effect of the chart format, the order in which the formats were flown had to be taken into account. Therefore, if the interaction were significant, the main effect for chart type was tested within each format order condition.

If the interaction were not significant ($p > .05$), then the assumption that format order did not interact with chart type could not be rejected. Subsequently, the data were combined across format order conditions, and a score was obtained by computing the mean difference between the search time for that variable for NOS charts and the search time for that variable for prototype charts. A t test was then conducted on this difference score to analyze the main effect for chart type.

The search time and accuracy results are reported in the same order in which they were obtained during an approach. These performance data are followed by a summary of the pilots' subjective preferences for chart formats.

3.2 QUICK REFERENCE QUESTION

Table 5 presents the mean search time (MST) required to answer the quick reference question for both chart formats. The t test conducted on the interaction of chart format and format order was not significant ($p < .217$). The data were then pooled across format order conditions and the results of the t test conducted on MST are summarized in Table 6. Pilots answered the quick reference question with a significantly ($p < .007$) faster MST for prototype charts

Table 5.
Mean Search Time (Seconds) Required to Answer: "What is the frequency of the [VOR or NDB]* that serves this approach, the final approach course, and the altitude at the final approach fix?"

Chart Format		
NOS	Prototype	Mean
13.25 (8.47)	5.53 (2.06)	9.39 (5.06)

Note: Standard deviations are given in parentheses.

*One of the items shown in brackets was chosen for any one chart.

Table 6.
T-Test of the Difference Between NOS and Prototype Charts for Mean Search Time (Seconds) Required to Answer: "What is the frequency of the [VOR or NDB]* that serves this approach, the final approach course, and the altitude at the final approach fix?"

Variable	N	Mean	Std Error	T	P > |T|
Difference in Elapsed Time	10	7.72	2.23	3.47	0.007

*One of the items shown in brackets was chosen for any one chart.

than for NOS charts. As depicted in Figure 11, the MST for the prototype format was more than twice as fast as the MST for the NOS format.

T tests were also conducted on the accuracy of pilots' answers to the quick reference question. Neither the interaction ($p < .733$) nor the main effect for chart format ($p < .100$) were significant.

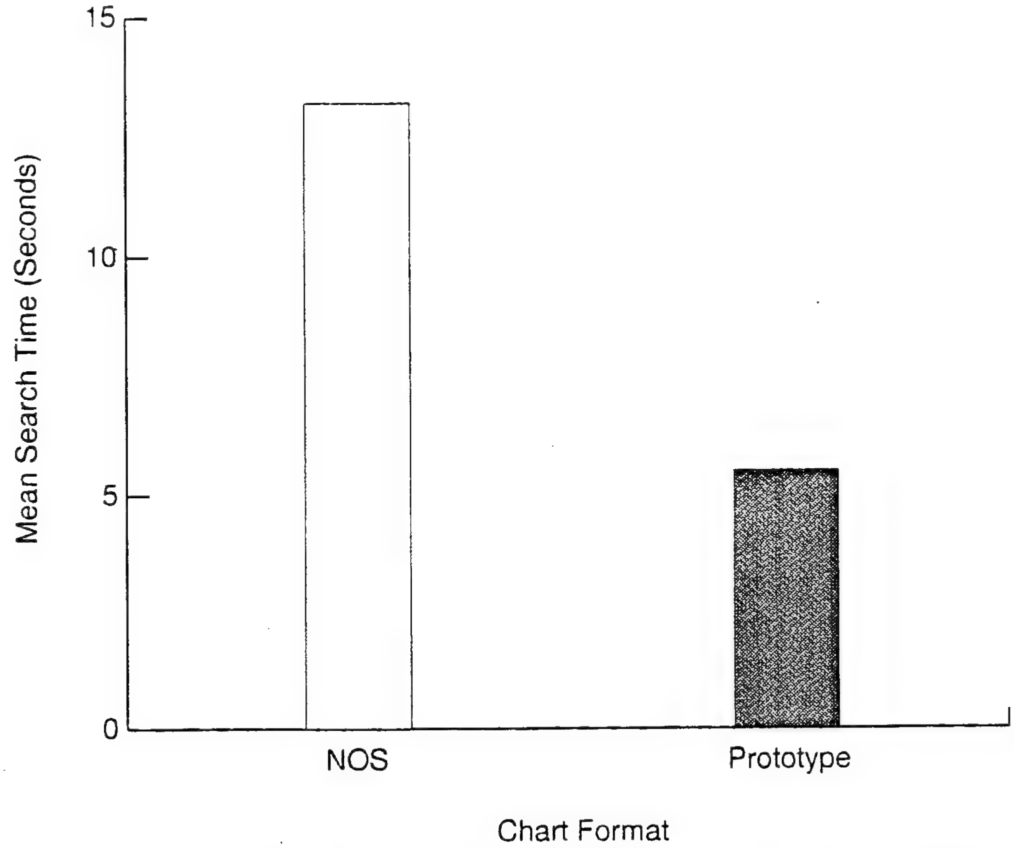


Figure 11. Mean Search Time (Seconds) Required to Answer: "What is the frequency of the [VOR or NDB] that serves this approach, the final approach course, and the altitude at the final approach fix?"

3.3 STUDYING FOR THE APPROACH

The next set of *t* tests were conducted on the MST required for pilots studying for the approach. No questions were asked during this period. Neither the interaction nor the main effect for chart format were significant ($p < .072$ and $p < .548$, respectively).

3.4 ANSWERING ALL QUESTIONS

Table 7 presents the MST needed to answer all 16 questions (shown in Table 3) for both chart formats. The *t* test conducted on the interaction of chart format and format order was not significant ($p < .064$). The data were then pooled across format order conditions and the results of the *t* test conducted on MST are summarized in Table 8. The MST required by pilots to answer questions was significantly ($p < .0001$) faster with prototype charts than with NOS charts. As depicted in Figure 12, MST for the prototype format was approximately nine seconds faster than MST for the NOS format.

This analysis was followed by *t* tests conducted on the accuracy of pilots' answers to the questions. Neither the interaction ($p < .191$) nor the main effect for chart format ($p < .483$) were significant.

Table 7.
Mean Search Time (Seconds) Required to Answer: Questions*

Chart Format		
NOS	Prototype	Mean
43.58 (16.09)	34.62 (14.41)	39.10 (15.13)

Note: Standard deviations are given in parentheses.

*These data do not include the mean search time to answer the quick reference question.

Table 8.
T-Test of the Difference Between NOS and Prototype Charts for
Mean Search Time (Seconds) Required to Answer: Questions*

Variable	N	Mean	Std Error	T	P > |T|
Difference in Elapsed Time	10	8.96	1.33	6.71	0.0001

Note: *These data do not include the mean search time to answer the quick reference question.

3.5 BRIEFING STRIP LAYOUT

Twelve of the 16 questions addressed items located in the prototype's briefing strip. Except for the radio frequencies and notes, the information in the briefing strip could also be found distributed throughout the prototype chart. In the NOS charts, all of these items were formatted in the current distributed layout.

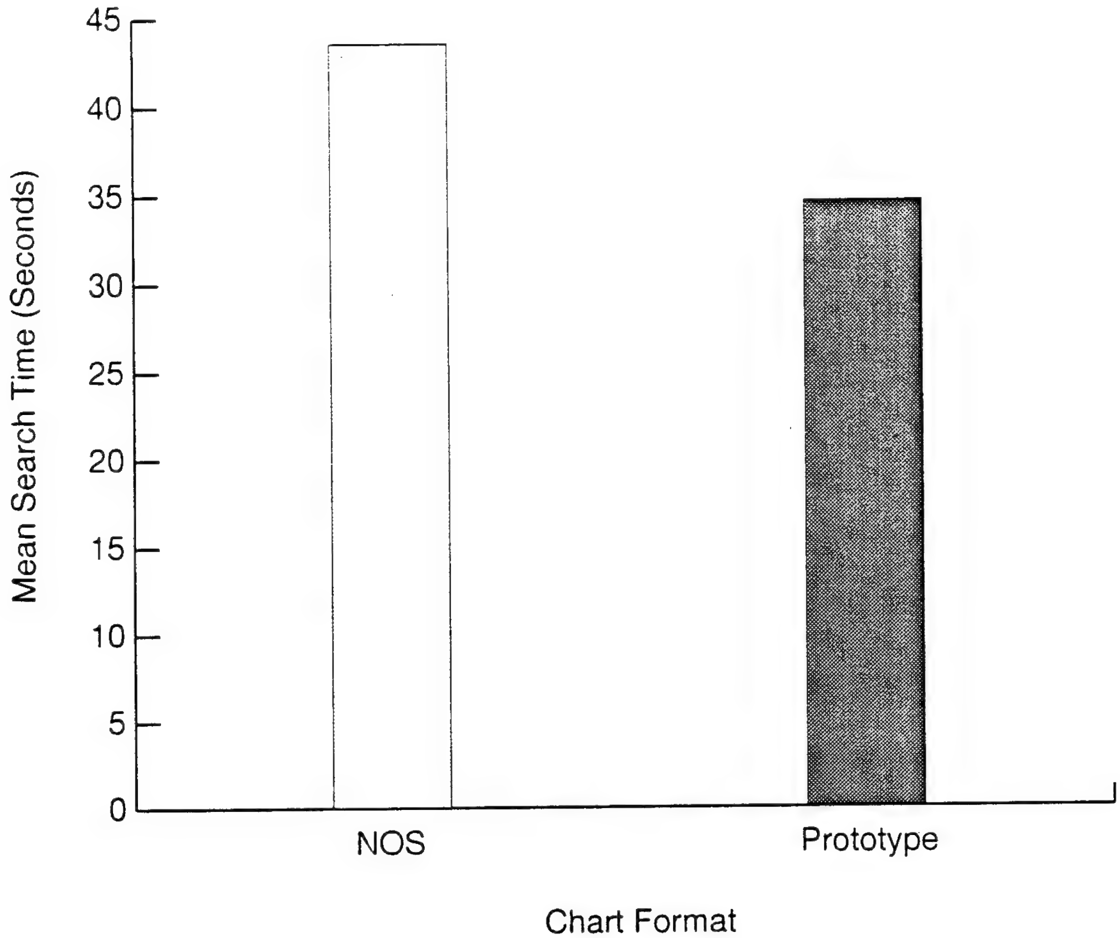


Figure 12. Mean Search Time (Seconds) Required to Answer Questions

Table 9 presents the MST to answer 11 of the 12 questions for both chart formats in both format order conditions. (The MST required to answer "In the missed approach procedures, what is the [first or second heading or first or second altitude]?" was analyzed separately and is discussed below.) The results of the *t* test conducted on the interaction of chart format and format order was significant ($p < .018$) as shown in Table 10. T tests were then conducted on the main effect of chart type within each format order condition, and the results are also summarized in Table 10. In both the NOS-then-prototype format order condition and the prototype-then-NOS format order condition, pilots answered the 11 questions significantly faster for prototype charts than for NOS charts ($p < .0001$ and $p < .047$, respectively). The interaction is depicted in Figure 13. The magnitude of the difference between mean search times for NOS and prototype charts is higher for the NOS-then-prototype format order condition. A detailed examination of this interaction is provided in the Discussion section of this report.

T tests were then conducted on the accuracy of pilots' answers to this subset of questions. Neither the interaction ($p < .257$) nor the main effect for chart format ($p < .366$) were significant.

Table 9.
Mean Search Time (Seconds) Required to Answer:
Questions* Regarding Information Included in the Briefing Strip

	Chart Format		
Format Order	NOS	Prototype	Mean
NOS then Prototype	38.64 (13.24)	27.12 (12.15)	32.88 (12.68)
Prototype then NOS	22.87 (4.65)	17.40 (2.19)	20.14 (2.94)
Mean	30.75 (12.52)	22.26 (9.69)	

Note: Standard deviations are given in parentheses.

*These data do not include the mean search time to answer the quick reference question, nor for the missed approach procedure question.

3.6 MISSED APPROACH INSTRUCTIONS QUESTION

Although the entire missed approach instructions were given in text format in both NOS and prototype charts, only prototype charts used icons to depict the "up and out" portion of the missed approach instructions. Table 11 shows the MST required by pilots to answer a question regarding this initial portion of the missed approach instructions. The t test conducted on the interaction of chart format and format order was not significant ($p < .202$). The data were then pooled across format order conditions and the results of the t test conducted on MST are summarized in Table 12. Pilots answered this question with a significantly ($p < .023$) faster MST for prototype charts than for NOS charts. The MSTs for both chart types are depicted in Figure 14.

Table 10.
T-Tests of Mean Search Time (Seconds) Required to Answer:
Questions* Regarding Information Included in the Briefing Strip

T-Test of the Difference Scores between NOS and Prototype for each Format Order

Format Order	N	Mean	Std Dev	Std Error
NOS then Prototype	5	11.52	1.58	0.71
Prototype then NOS	5	5.46	4.30	1.92

Test of the Equality of Variances

Variances	DF	T	P > |T|
Unequal	5.1	2.96	0.031
Equal	8	2.96	0.018

For Ho: Variances are equal, F' = 7.39, DF = (4,4), Prob > F' = 0.078

NOS then Prototype Format Order: T-Test of the Difference Between NOS and Prototype

Variable	N	Mean	Std Error	T	P > |T|
Difference in Elapsed Time	5	11.52	0.71	16.30	0.0001

Prototype then NOS Format Order: T-Test of the Difference Between NOS and Prototype

Variable	N	Mean	Std Error	T	P > |T|
Difference in Elapsed Time	5	5.46	1.92	2.84	0.047

Note: *These data do not include the mean search time to answer the quick reference question, nor for the missed approach procedure question.

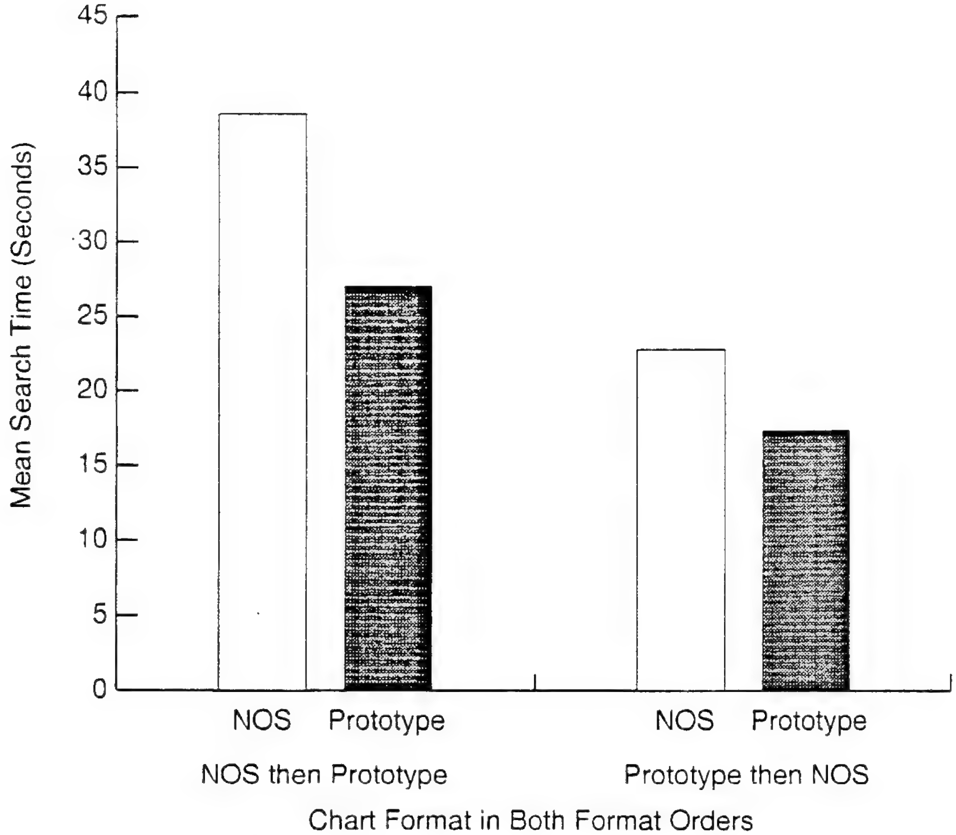


Figure 13. Mean Search Time (Seconds) Required to Answer Questions Regarding Information Included in the Briefing Strip

Table 11.
Mean Search Time (Seconds) Required to Answer: "In the missed approach procedures, what is the [first or second heading or first or second altitude]*?"

Chart Format		
NOS	Prototype	Mean
2.76 (1.16)	1.98 (0.60)	2.37 (0.81)

Note: Standard deviations are given in parentheses.

*One of the items shown in brackets was chosen for any one chart.

Table 12.
T-Test of the Difference Between NOS and Prototype Charts for Mean Search Time (Seconds) Required to Answer: "In the missed approach procedures, what is the [first or second heading or first or second altitude]*?"

Variable	N	Mean	Std Error	T	P > |T|
Difference in Elapsed Time	10	0.77	0.28	2.74	0.023

*One of the items shown in brackets was chosen for any one chart.

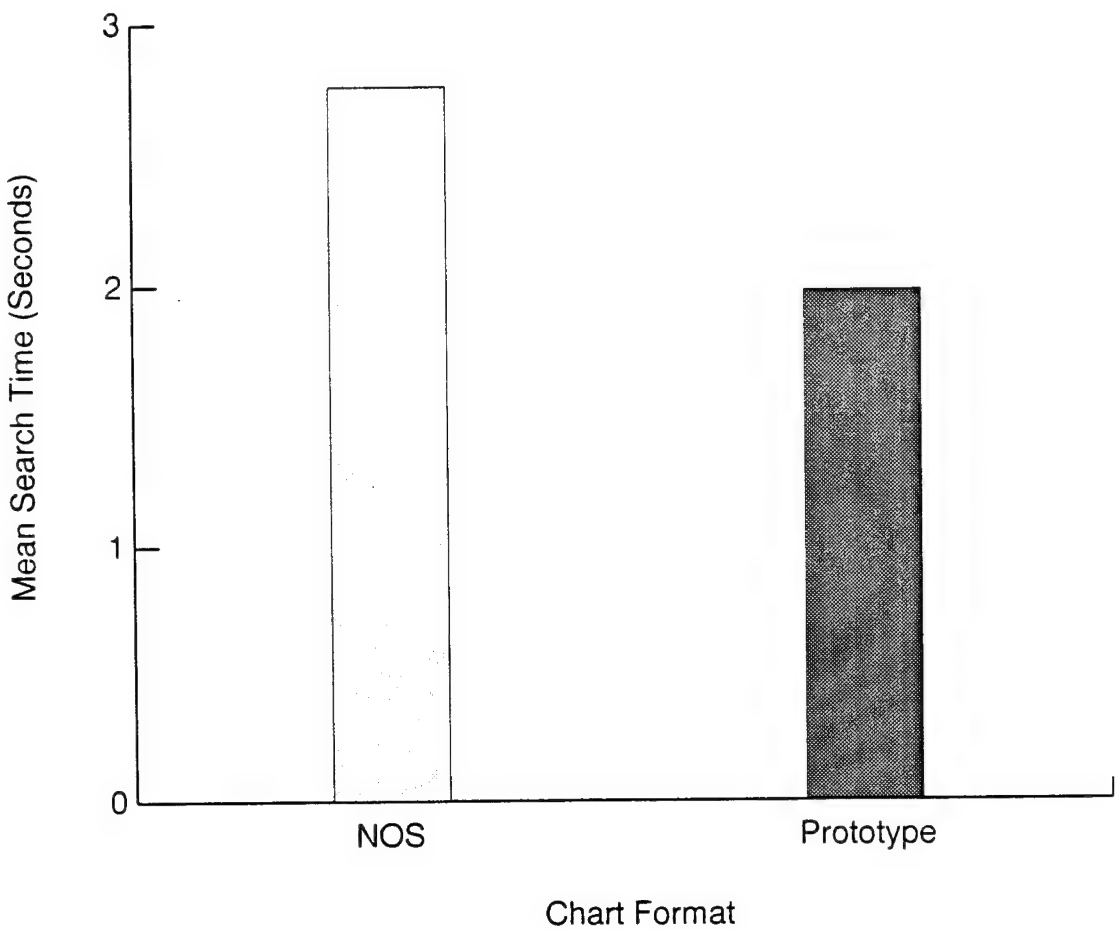


Figure 14. Mean Search Time (Seconds) Required to Answer: "In the missed approach procedures, what is the [first or second heading or first or second altitude]?

Pilots made no errors in answering the missed approach instruction question while using either chart type.

3.7 PILOT PREFERENCES FOR CHART FORMATS

The experimenter asked pilots whether they preferred one of the chart formats, or had no preference for accomplishing the following: answering the quick reference question, reviewing the approach, executing the approach, and executing the missed approach. The pilots' responses are summarized in Table 13, and their comments are provided in Appendix I.

The NOS chart was never preferred by any pilot for performing any of the tasks. The prototype chart was unanimously preferred for answering the quick reference question and for executing the missed approach procedures.

3.8 PILOT COMMENTS

The experimenter asked pilots to list the features of the prototype chart which they did not use. The pilots' responses are summarized in Table 14, and their comments are also provided in Appendix I. Five items were mentioned. All five were features shown in the briefing strip which are also shown in their usual location on current NOS charts.

Finally, the experimenter asked pilots if they had any other comments. All of the pilots' responses were in regard to the prototype chart. Table 15 summarizes their comments which are provided in Appendix I. Again, the briefing strip was the pilots' primary subject for comments.

Table 13.
Pilot Preferences for Each Chart Format for
Quick Reference and Each Approach Phase

	Chart Format		
Approach Phase	NOS	Prototype	No Preference
Quick Reference	0	10	0
Studying	0	8	2
Executing	0	6	4
Missed Approach	0	10	0

Table 14.
Pilot Responses to "What Features of the Prototype Chart Did You Not Use?"

Briefing Strip Feature Not Used	Number of Pilots Citing That Feature
Airport Elevation	6
Final Approach Fix Information	5
Final Approach Course	5
Approach Lighting Sketch	1
Frequency of Primary Navaid	1

Table 15.
Pilot Responses to "Do You Have Any Other Comments?"

Prototype Chart Feature	Positive Comments	Negative Comments
Briefing Strip	11	2
Highlighting Text with Bolding and Boxing	8	0
MSA Circle	6	0
Iconic Missed Approach Instructions	1	0

4. DISCUSSION

4.1 MAJOR FINDINGS

The objective of this experiment was to evaluate the effectiveness of the prototype IAP chart design in transferring information to pilots during actual flight. Four specific hypotheses were tested, and each one predicted that pilots would retrieve information faster and more accurately with the prototype format than with the NOS format. Pilots were consistently faster when answering questions with the prototype format. This significant increase in speed was obtained at no cost to accuracy. Pilots were as accurate in answering questions using the prototype format as they were with the more familiar NOS format.

The first hypothesis stated that the formatting of the briefing strip would produce faster and more accurate retrieval of the information it contained than the formatting of that information on NOS charts. The particular analyses that provided the test of this hypothesis are those for the quick reference question, studying for the approach, and the briefing strip layout. Data for the missed approach instruction question were analyzed separately from the briefing strip data.

The quick reference question asked "What is the frequency of the [VOR or NDB] that serves this approach, the final approach course, and the altitude at the final approach fix?". When pilots were using the prototype chart, they found the answer to this question more than twice as fast as when they were using the NOS chart. This significant difference is depicted in Figure 11. The reason for this difference may be seen by examining the charts in Appendix D. The first three boxes in the top line of the prototype's briefing strip give this information. In order to answer the question with the NOS chart, pilots had to search through the plan and profile views. The pilot comments in Appendix I support this explanation. Pilots unanimously preferred the prototype chart for answering the quick reference question (see Table 13).

The briefing strip formatting was also expected to reduce the amount of time pilots spent when they were studying to prepare for executing the approach. Because much of the critical information was located close together, pilots were expected to retrieve the information more quickly. However, the data did not support this expectation. No significant difference for mean search time (MST) was found between chart formats. One explanation for not detecting a difference between the chart formats is that the pilots' major areas of interest on the chart when they studied the approach were the plan view in particular, as well as the profile view. An examination of the chart formats reveals few differences between the prototype and NOS charts in these sections of the charts. Since no questions were asked during this period, pilots may have spent the majority of their time studying chart features which were common to both chart formats. Although no statistically significant difference was found for MST while studying, eight of the 10 pilots still preferred the prototype chart for studying for the approach, as shown in Table 13 and Appendix I.

Different results were found when pilots were asked to search for information contained in the briefing strip. Although there was a significant interaction between chart format and the order in which the pilots used the two formats, the prototype chart produced significantly faster MST in both format order conditions, as shown in Figure 13. The interaction is statistically

significant because the magnitude of the difference between MST for NOS and prototype charts is higher for the NOS-then-prototype format order condition. Two probable causes combined to produce the interaction. Both causes will be discussed individually, followed by an explanation of how their combination resulted in the interaction.

The first cause was that pilots spent a substantial portion of their attention on learning how to perform the experimental procedures while flying an unfamiliar airplane. Although the pilots were trained in the Frasca flight simulator in the general flight procedures and experimental methods, they still needed to learn how to transfer the skills they learned in the laboratory to actual flying in the Baron. None of the pilots had flown this particular airplane before, and all of the pilots were having their first experience with using GPS guidance to fly approaches. Learning to perform the experimental procedures while flying an unfamiliar airplane decreased the pilots' attention resources available for searching for information on the chart. As the day progressed, pilots became more and more familiar with both how the airplane handled, and how to integrate the GPS guidance into their maneuvering. As pilots completed their learning, the attention resources available for searching through the chart increased. Therefore, in the morning session, pilots had less available attention for searching for information to answer questions than in the afternoon session.

In order to explain the interaction, two effects still need to be explained. These effects are best expressed as questions. The first is: why is the MST for the NOS-then-prototype format order slower than the MST for the prototype-then-NOS format order? The second question is: why would the MST for NOS charts flown in the afternoon be faster than the MST for prototype charts flown in the afternoon? Assuming the pilot groups were not different on some critical value (a review of pilot characteristics did not reveal such a difference), there must be something else going on. Consider the pilots in the prototype-then-NOS format order condition. Perhaps it was so easy to use the prototype chart in the morning that pilots were able to learn the flying and GPS navigation tasks very well, so that by the time they were answering questions with the NOS charts in the afternoon, they were able to dedicate an optimal amount of attention resources to search for the answers with an effective search strategy. In the morning session, when pilots had less attention available for searching for information to answer questions, the prototype's briefing strip was very helpful. By the end of the morning session, they had already learned how to both fly the airplane and use GPS information. Even so, these pilots would still be expected to have an MST that was lower for the prototype than for the NOS format, and that was the case.

Now consider the pilots in the other format order condition, the one in which the NOS chart was flown in the morning. These pilots may have had such a difficult time searching for answers with a lesser amount of available attention, that they never really learned either effective search strategies for the NOS format, nor did they learn enough about how the airplane handles and how to navigate with GPS information in order to avoid continuing the learning process into the afternoon. Although the MST for the prototype would still be expected to be lower than the MST for NOS, these pilots would be expected to show relatively high MSTs for both the NOS and prototype formats compared to the pilots who flew with the prototype in the morning. That is what the data show.

These causes would explain the difference in MSTs between the format order conditions (the NOS-then-prototype format order condition had a higher MST than the prototype-then-NOS format order condition), and it would explain the consistent direction of the differences between the formats in both format order conditions (prototype was faster in both format order conditions). These causes would also explain the difference in the magnitude of the between-format difference within each format order condition (a bigger difference for the NOS-then-prototype format order condition than for the prototype-then-NOS format order condition).

The second hypothesis stated that the iconic missed approach instructions would elicit faster and more accurate information retrieval than the text instructions. The test of this hypothesis was provided by the analyses for the missed approach instruction question. Pilots were asked "In the missed approach procedures, what is the [first or second heading or first or second altitude]?" As shown in Tables 11 and 12 and Figure 14, the MST required by pilots to answer the missed approach question was significantly faster for the prototype format than for the NOS format.

The missed approach question pertained to the "up and out" portion of the missed approach instructions. Both charts provided the full instructions in text. On the prototype, this text was placed in the briefing strip, while on the NOS, the text appeared in the profile view. Only the prototype provided the up and out portion in icons. In light of the pilots' comments given in Appendix I, the faster MST for the prototype format can be attributed to the icons. Because of the icons, plots unanimously preferred the prototype chart for executing the missed approach procedures. These results provide strong support for the second hypothesis.

The third hypothesis predicted that overall, the prototype chart would produce faster and more accurate information transfer than the NOS chart. This hypothesis was tested by the analysis for answering all questions shown in Table 3. As presented in Tables 7 and 8, the MST required by pilots to answer questions was significantly faster with prototype charts than with NOS charts. Figure 12 shows that the MST for the prototype format was approximately nine seconds faster than MST for the NOS format. The data provide strong support for the third hypothesis. This result would be expected since 12 of the 16 questions pertained to items in the prototype's briefing strip, and the faster MSTs shown for that format have been discussed above.

The fourth hypothesis stated that pilots would prefer the prototype format to the NOS format. Pilot comments were used to test this hypothesis. These comments are provided in Appendix I and summarized in Table 13. Pilots were asked whether they preferred one of the chart formats, or had no preference for performing the following: answering the quick reference question, reviewing the approach, executing the approach, and executing the missed approach.

The NOS chart was never preferred by any pilot for performing any of the tasks. The prototype chart was unanimously preferred for answering the quick reference question and for executing the missed approach procedures. Eight of the 10 pilots preferred the prototype format for studying for the approach. Six pilots preferred the prototype format for executing the approach. Pilots were probably searching through the plan and profile views while

executing the approach, and these sections are quite similar in both formats. That is why the very strong preference for the prototype chart which was shown in the other approach phases was not as strong for this phase. Note that while four pilots did not express a strong preference for either format when executing the approach, the NOS format was never chosen.

Pilots were also asked to list the features of the prototype chart that they did not use. The purpose of this question was to determine if specific features of the prototype were not useful and/or should be redesigned. Another reason for this question was to determine if the pilots took advantage of the prototype's features, or whether they ignored the design differences and used it like the NOS chart. Both the MST data and pilot comments indicate that pilots took advantage of the prototype's features.

An interesting theme in the comments is shown in Table 14. Every feature mentioned is located in the briefing strip. The items in the briefing strip that pilots most often cited as not being used were the airport elevation, final approach fix information, and final approach course. This is not to say that they did not need this information, only that those particular pilots did not refer to the briefing strip for those items.

Examination of the comments in Appendix I and the NOS format shown in Appendix D reveals that these three features already have consistent locations on the NOS chart. The airport elevation is always boxed in the upper left corner of the airport sketch. Every pilot who cited this feature said that he/she looked at the airport sketch for that information. The final approach fix information and final approach course are consistently placed in the center of the profile view. Every pilot who cited these features said he/she looked at the profile view for these items. These pilots did not take advantage of the briefing strip formatting because they were used to looking someplace else. The prototype format still allowed them to do this, by retaining the current placement of those items in the airport sketch and profile view, as well as in the briefing strip.

Finally, pilots were asked another open-ended question - if they had any other comments. These comments are provided in Appendix I and summarized in Table 15. All of the comments pertained to the prototype chart. Twenty six of the 28 comments were positive.

In summary, the pilots' comments indicate an overwhelming preference for the prototype format. Very strong support was found for the hypothesis that pilots would prefer the prototype format to the NOS format. In most cases this preference for the prototype format was associated with improved performance on the objective measures.

4.2 SUMMARY OF MAJOR FINDINGS

- Pilots used the prototype's briefing strip to search for information to answer questions pertaining to the content of the briefing strip. They found the information faster this way than when they used the NOS format to answer those questions.

- When pilots searched for information on the charts in order to answer all the questions, they found information faster on the prototype chart than on the NOS chart.

- When pilots searched for information on the charts in order to answer all the questions, no difference was found between the accuracy of the answers given when pilots used the prototype and when they used the NOS format.
- Pilots found information regarding the "up and out" portion of the missed approach instructions faster when they used the iconic missed approach instructions on the prototype chart than when they used text instructions on the NOS chart.
- Most pilots preferred the prototype format for reviewing the approach.
- All pilots preferred the prototype format for executing the missed approach. Their preference was due to the use of icons to depict the up and out portion of the missed approach instructions.
- None of the pilots preferred the NOS format for executing any approach phase.

4.3 CONCLUSION

Pilots were able to find information faster on the Volpe prototype chart than on the NOS chart, and they indicated a clear preference for the prototype format over the NOS format. These findings are consistent with the outcome of past laboratory experimentation (Multer, Warner, DiSario, and Huntley, 1990; Osborne and Huntley, 1992), subject matter expert interviews (Osborne and Huntley, 1993), a review of the relevant literature (Mangold, Eldredge, and Lauber, 1992), and a field evaluation (Blomberg, Bishop, and Hamilton, in press).

Based on all of the above findings, the National Ocean Service is strongly urged to adopt the prototype format for its IAP charts.

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APPENDIX A

INFORMED CONSENT FORM

Informed Consent Form

You have been asked to participate in the Prototype Instrument Approach Procedure Chart Study conducted by the Operator Performance Division of the Volpe National Transportation Systems Center (VNTSC). The study's purpose is to assess the speed and accuracy with which pilots are able to read information from different kinds of approach chart designs. If you agree to participate, you will be asked to participate for two days. On one day you will fly a Beechcraft Baron BE55 aircraft, and on the other day you will fly a Frasca flight simulator.

During both flying sessions, you will fly a series of GPS approaches with different kinds of approach charts. After reviewing the information in your usual method, you will be asked a series of questions regarding information found on the approach chart. In order to answer the question, you will be able to answer from memory or push a switch to open a shutter and read the chart. As you fly the simulator and the Baron, we will score your crosstrack error and deviations from desired altitude and airspeed. You will also be asked to complete short questionnaires regarding your flight experience and instrument approach procedure chart use. After the flight session has been completed, you will be asked for your opinions on the different chart designs.

You will have the choice between flying the approaches under a hood or with foggles. All approaches will be flown at Gardner Municipal Airport (GDM). The charts you will use in the airplane (and in the simulator) will depict data that is not approved for IFR approaches, however, there will be a safety pilot in the Baron. If the safety pilot becomes incapacitated, remove the instrument hood or foggles and assume pilot-in-command status for flying the aircraft. A full set of accurate instrument approach charts for GDM, Hanscom (BED) and the surrounding airports will be available to you at all times.

The experiment will take approximately 8 hours each day to complete. Please do not hesitate to ask questions about the study at any time. Your data will be kept strictly confidential and your name will not be associated with your data. Your participation in this study is strictly voluntary. If you agree to participate, and you are a Volpe Center employee, you will be given a VNTSC account number to which you may charge your time. If you are not a Volpe Center employee, your expenses will be reimbursed according to the terms stated on the reimbursement form. You are free to withdraw at any time without penalty, and your participation is sincerely appreciated.

____________________________ ____________________________

Signature and Age of Participant   Signature of researcher

____

Name (please print)   Date

____

Address and Daytime Phone Number

APPENDIX B

FLIGHT EXPERIENCE AND CHART PREFERENCE QUESTIONNAIRE

Pilot Questionnaire

Thank you for participating in this research - your contribution is vital. Unlike the vast majority of aviation human factors research, much of the work conducted here at the Volpe Center Cockpit Human Factors Lab is specifically focused on the general aviation pilot. This research is paid for by the FAA and the results will provide a basis for making decisions that will increase air safety for all pilots and for general aviation pilots in particular. It could not be accomplished without pilots like you and we sincerely appreciate your participation.

Your name will not be associated with your data. However, we do need to ask you for some descriptive information since it may help us later on when we are studying trends in the data.

1. Age: _____ Gender: Male Female

2. Approximately, what is your: total flight time _____ hours

total instrument time _____ hours

3. Please indicate your areas of aviation experience, and for each area, please circle the approach category(ies) of aircraft most often flown:

Military A B C D E   Part 121 B C D   Part 135 A B C

General Aviation A B C   Corporate A B C D

4. Please estimate the percentage of time you use the following instrument approach procedure charts:

Jeppesen _____%

NOAA _____%

Other (please identify)___________________________%

5. Please rank your preference for these manufacturers' instrument approach procedure charts (1 = most preferred, 3 = least preferred - if you do not use one of these types of charts, write "NA"):

Jeppesen _____

NOAA _____

Other _____

APPENDIX C

DESCRIPTIONS OF THE FLIGHT PROCEDURES FOLLOWED IN THE SIMULATOR AND AIRPLANE

Pilot Brief - Frasca Flight Simulator Procedures

Your task will be to fly instrument approaches using either NOS or prototype IAP charts. After having an opportunity to review the approach you will fly the procedure, and the experimenter will ask you a series of questions regarding information on the chart. All approaches will be flown at Gardner Municipal Airport (GDM).

During the approaches, course guidance will be provided by a simulated GPS receiver display, presented on a CRT in the center of the instrument panel. The simulated receiver will drive the CDI on the HSI in front of you. Needle sensitivity will be set to 3/10 nm full scale. The receiver's display will show the waypoint you are flying to, the distance to that waypoint, and the bearing to that waypoint.

To begin each approach, the experimenter will position you approximately 12 nm from the initial approach fix. You will be given the chart to review while you are flying to the initial approach fix.

As you approach the missed approach point (MAP) the experimenter may instruct you to land. If you are instructed to land, remove your foggles/hood, slow to 90 knots, and descend to the field elevation. If he does not instruct you to land, fly the missed approach procedures as depicted on the approach chart. Reconfigure the aircraft as usual for the climb, with a target airspeed of 120 knots.

Fly to the same standards you trained to for your instrument practical test. Fly each approach at 120 knots ± 10 knots, and maintain the altitudes ± 100 feet. Do not descend below the MDAs shown for Category B aircraft.

Some useful approximations for maintaining 120 knots with the Frasca:

level flight - gear up, flaps up:	RPM 2400	MP 16 - 17"
level flight - gear down, flaps 50%:	RPM 2700	MP 18"
1000 fpm descent - gear down, flaps 50%:	RPM 2700	MP 15"

Pilot Brief - Baron Flight Procedures

Today's flight procedures are basically the same as those used during your session in the Frasca. Your task will be to fly instrument approaches using either NOS or prototype IAP charts. After having an opportunity to review the approach you will fly the procedure, and the experimenter will ask you a series of questions regarding information on the chart. All approaches will be flown at Gardner Municipal Airport (GDM).

During the approaches, course guidance will be provided by a Garmin 155 TSO GPS receiver. The safety pilot will be responsible for operating the GPS receiver. The receiver has its own CDI and will also drive the CDI on the HSI in front of you. Needle sensitivity for both the receiver's CDI and the CDI on your HSI will be set to 3/10 nm full scale. The receiver's display will show the waypoint you are flying to, the distance to that waypoint, and the bearing to that waypoint.

To begin each approach, the safety pilot will give you vectors that will allow you to intercept the approach course and cross the initial approach fix on course. While you are flying these vectors, you will be given the chart, and you may then begin your review of the approach.

As you approach the missed approach point (MAP) the experimenter may instruct you to land. If you are instructed to land, remove your foggles/hood, slow to 90 knots, and continue the approach visually to a full stop landing. If he does not instruct you to land, fly the missed approach procedures as depicted on the approach chart. Reconfigure the aircraft as usual for the climb, with a target airspeed of 120 knots.

Fly to the same standards you trained to for your instrument practical test. Fly each approach at 120 knots ± 10 knots, and maintain the altitudes ± 100 feet. Do not descend below the MDAs shown for Category B aircraft. If you exceed these standards, the safety pilot will bring it to your attention.

If the safety pilot tells you that he has control of the aircraft, you should give him the controls and tell him he has control.

If the safety pilot becomes incapacitated, remove the foggles/hood and assume pilot-in-command status. A full set of current IAP charts will be available to you at all times.

Some useful approximations for maintaining 120 knots with the Baron:

level flight - gear up, flaps up:	RPM 2300 - 2500	MP 15"
level flight - gear down, flaps 15°:	RPM 2300 - 2500	MP 17"
1000 fpm descent - gear down, flaps 15°:	RPM 2500	MP 15"

APPENDIX D

CHARTS AND APPROACH LIGHTING SYSTEM SKETCHES USED FOR TRAINING

VOLPE CENTER CHART-NOT FOR NAVIGATION

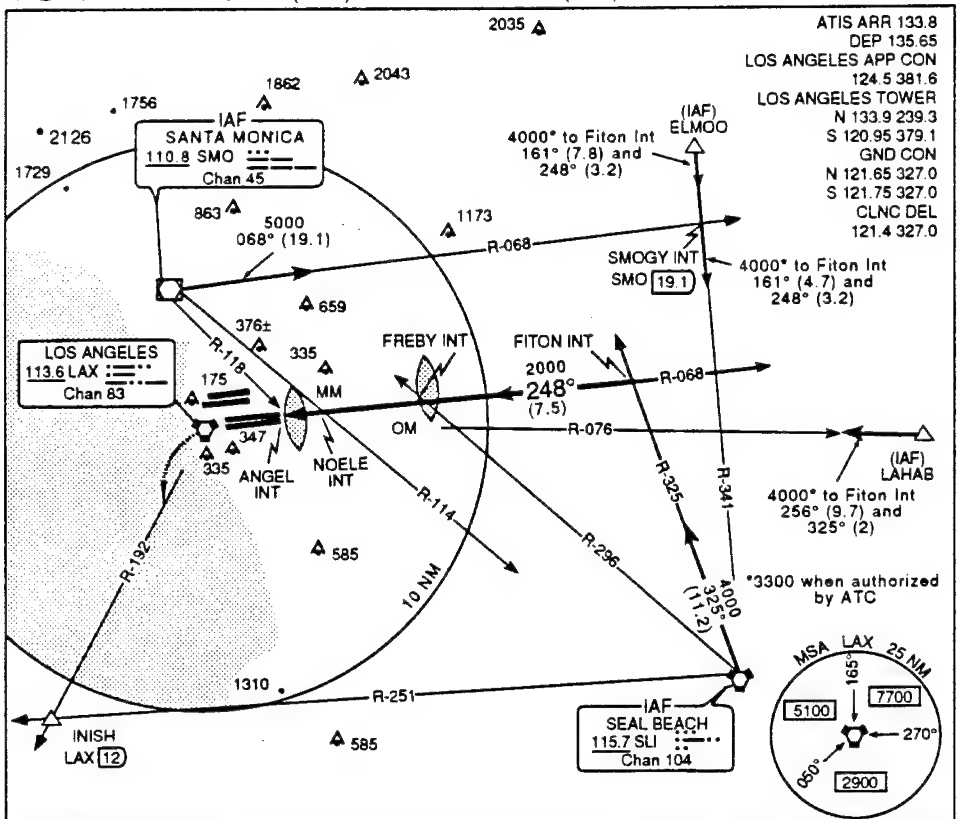
Call (617) 494-2362 or 2339 with questions or comments

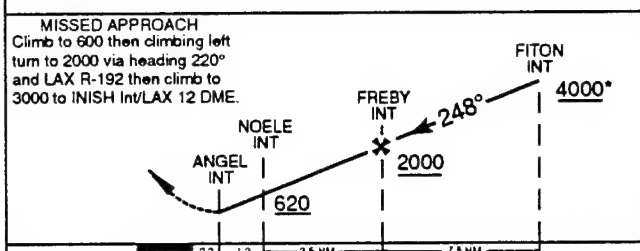
Amdt 15 920098

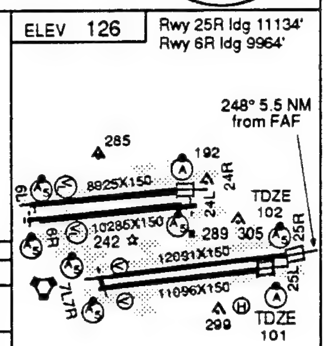
VOR RWY 25R (GPS)

AL-237 (FAA)

LOS ANGELES INTL (LAX)
LOS ANGELES, CALIFORNIA







CATEGORY	A	B	C	D
S-25R**	620/24 519 (500-½)		620/50 519 (500-1)	620/60 519 (500-1¼)
CIRCLING	620/24 518 (500-½)		620/50 518 (500-1)	620/60 518 (500-1¼)

**Cat. D visibility increased to RVR 6500 for inoperative ALSF-2.
ADF or radar required.

TDZ/CL Rwys 6R, 24R and 25L
HIRL all Rwys

FAF to MAP 4.8 NM					
Knots	60	90	120	150	180
Min:Sec	4:48	3:12	2:24	1:55	1:36

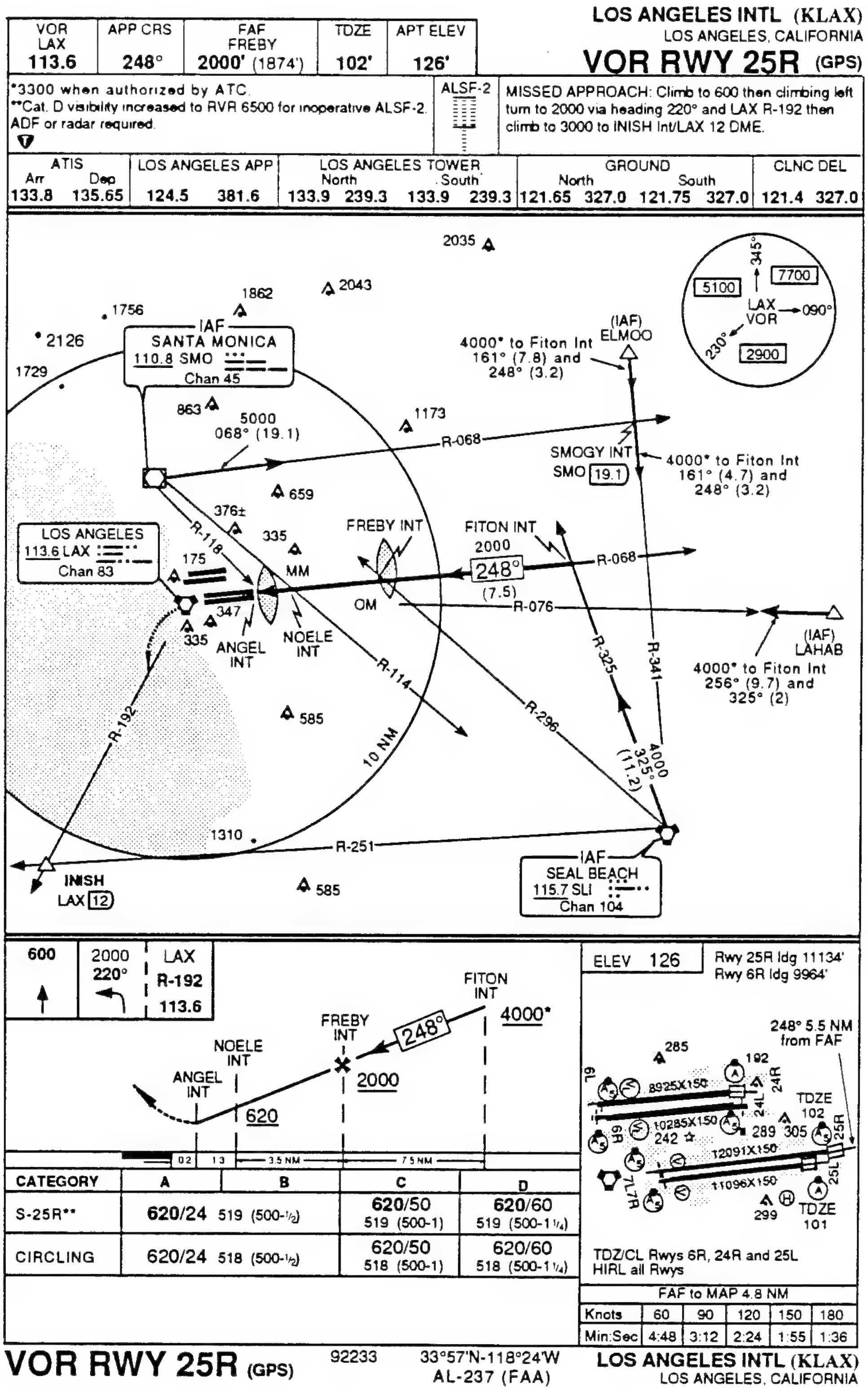
VOR RWY 25R (GPS)

33°57'N-118°24'W

LOS ANGELES, CALIFORNIA
LOS ANGELES INTL (LAX)

VOLPE CENTER CHART-NOT FOR NAVIGATION

Call (617) 494-2362 or 2339 with questions or comments



ALSF-1

TYPE 1

ALSF-2

TYPE 2

HIRL

TYPE 3

APPENDIX E

TRAINING GUIDES FOR BOTH THE NOS AND PROTOTYPE FORMAT CHARTS

Briefing Guide for the NOS Format Instrument Approach Procedure Chart

[Use the NOS LAX GPS Overlay VOR Rwy 25R as the example.]

As an IFR pilot, you are already very well practiced in interpreting the content of IAP charts. Even though you are currently familiar with the NOS design, it's important to review the location of key information.

[During the review, actually point to each of the information elements listed below. Describe the location and content of each element.]

Plan View

- communication frequencies
- approach course
- location of information (type, identifier, and frequency) for the navaid that serves the approach
- MSA circle
- identification of the reference navaid on the perimeter and in the center of the circle
- segments defined by bearing from the navaid
- missed approach holding fix

Profile View

- missed approach instructions
- approach course
- MSL altitude at the FAF

Minimums

- MDAs

Notes

- notes are given in both this section and in the plan view

Airport Sketch

- touchdown zone elevation
- airport elevation
- approach lighting system sketch

Briefing Guide for the Prototype Format Instrument Approach Procedure Chart

[Use the prototype LAX GPS Overlay VOR Rwy 25R as the example.]

Background The purpose of the prototype is to improve the speed and accuracy with which pilots locate and comprehend information on instrument approach procedure (IAP) charts. It is an attempt to change the formatting of the information to conform more closely to the way pilots actually use the information. This format was developed from a combination of laboratory experimentation conducted by the Cockpit Human Factors Program here at the Volpe Center, a field evaluation conducted at the training centers of four airlines, and several in-depth subject matter expert reviews.

Features of the Prototype

1. Briefing Strip - These three rows of information are used for preparing for the approach. The location of each information element is standardized and given in the order in which it will be used. In the first and third lines of the strip, the information to be briefed is given in bold type, while the name of the information is shown in regular type. The pilot no longer has to search through the entire chart to assemble this data.

1.1. The information required for quick reference is in the top row. The first box contains the type, identifier, and frequency of the navaid that serves this approach. [Point out the contents of the other boxes.] If the charted procedure were a non-precision approach to either of two runways, both TDZEs would be shown, and both will be bolded. To the right of this row, the four-letter ICAO airport identifier is shown in small italics.

1.2. The second row contains all equipment and procedural notes (navigation notes remain in the profile section), an approach lighting system sketch, and missed approach instructions. If any visual glideslope indicators are present, they are also depicted in the approach lighting system sketch. If a parallel runway has the same lighting system, an italicized note is given in the notes box.

1.3. The ATIS and communication frequencies are listed in order of their use and the numbers are always shown under the labels. In order to save space, they are not as large as the numbers listed above. They are made available here for verification, early radio set-up, or in case of blockage of an active communication channel. Since the plan view is oriented North-up, the West and East frequencies are placed on the left and right, respectively.

2. MSA Circle - The MSA circle will float within the plan view to occupy unused space.

2.1. The text identification for the reference navigational aid (navaid) is given in the center of the circle.

2.2. The sectors of the circle are defined by radials rather than bearings, since pilots usually think in terms of radials rather than bearings to the station.

3. Plan View -

3.1 The approach course number has been boxed to enhance detectability and readability.

3.2 The name of the missed approach holding fix has been bolded.

4. Profile View -

4.1. In the profile view, the "up and out" portion of the missed approach instructions is depicted in icons rather than text. These icons tell the pilot all that is required to get the plane up and out - and this critical information is more easily located than if it were embedded in text. The first altitude and navaid frequency are emphasized by bolding. If there was a heading in the first box, it too would be bolded.

4.2 The approach course number has been boxed here as well.

5. Minimums -

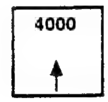
5.1 Bold type has been used to make the MDAs easier to find and read.

APPENDIX F

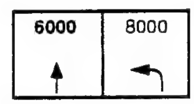
TRAINING MATERIAL FOR ICONIC MISSED APPROACH INSTRUCTIONS

The Use of Icons for Missed Approach Instructions

Climb to 4000

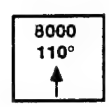


Climb to 6000 then climbing left turn to 8000

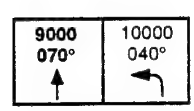


Note that the first altitude (6000) is in bold print.

Climb to 8000 heading 110°

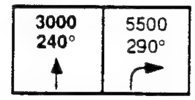


Climb to 9000 heading 070° then climbing left turn to 10000 heading 040°



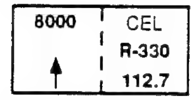
Note that both the first altitude (9000) and the first heading (070°) are in bold print.

Climb to 3000 heading 240° then climbing right turn to 5500 heading 290°

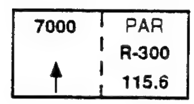


Climb to 8000 to intercept CEL R-330
(112.7 is the frequency for CEL)

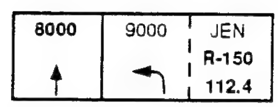
Note that the radial (R-330) and frequency (112.7) are in bold print.



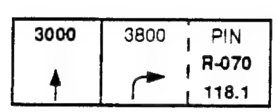
Climb to 7000 to intercept PAR R-300



Climb to 8000 then climbing left turn to 9000 to intercept JEN R-150



Climb to 3000 then climbing right turn to 3800 to intercept PIN R-070



Climb to 4500 heading 100° then climbing left turn to 6000 via heading 042° and GAM R-260

4500	6000	GAM
100°	042°	**R-260**
↑	↰	**110.9**

Climb to 2000 heading 128° then climbing right turn to 3300 heading 155° to intercept BIR R-330

2000	3300	BIR
128°	155°	**R-330**
↑	↱	**112.6**

Climb to 6000 heading 040° then climbing right turn to 7800 heading 080° to intercept MAZ R-260

6000	7800	MAZ
040°	080°	**R-260**
↑	↱	**113.9**

Climb to 4000 heading 135° then climbing left turn to 6300 heading 109° to intercept KAN R-305

4000	6300	KAN
135°	109°	**R-305**
↑	↰	**110.3**

Climb to 5000 heading 108° then climbing right turn to 7200 heading 115° to intercept KER R-310

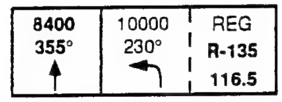
5000	7200	KER
108°	115°	**R-310**
↑	↱	**117.2**

APPENDIX G

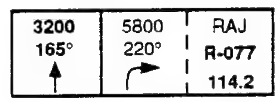
SELF-TEST FOR ICONIC MISSED APPROACH INSTRUCTIONS

Please read this before continuing: *Use this page to determine whether or not the icons are clear to you. Interpret the icons before moving the card to check the text.*

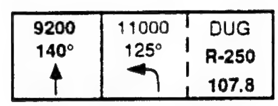
Climb to 8400 heading 355° then climbing left turn to 10,000 heading 230° to intercept REG R-135



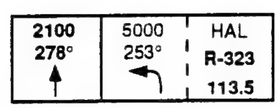
Climb to 3200 heading 165° then climbing right turn to 5800 heading 220° to intercept RAJ R-077



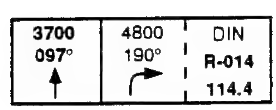
Climb to 9200 heading 140° then climbing left turn to 11,000 heading 125° to intercept DUG R-250



Climb to 2100 heading 278° then climbing left turn to 5000 heading 253° to intercept HAL R-323



Climb to 3700 heading 097° then climbing right turn to 4800 heading 190° to intercept DIN R-014



APPENDIX H

TRAINING GUIDE FOR LIGHT SHUTTER OPERATION

Briefing Guide for the Liquid Crystal Light Shutter

Throughout the study, you will be looking for information on the charts. We need to keep track of how often and for how long you look at the charts, and this light shutter allows us to do that. It is controlled by the push-to-talk type switch which has been Velcroed to the left yoke handle.

A chart will be placed under the shutter. When you want to open the shutter and look at the chart, press the switch [demonstrate].

[Allow the pilot to open and close the shutter several times. Ask the pilot if the switch is in a place that's comfortable and easy to reach. Make your own assessment of the placement of the switch. Does the pilot appear to be comfortable? Does the switch appear to be easy to reach?]

During the experiment, you may look at the chart whenever you need to. However, we want to emphasize that you should minimize the number of looks, and the length of each look. This is a very important point. You may look at the chart whenever you need to, but when you look at the chart try to minimize the number of times you look at the chart, and try to keep the length of each look to a minimum. By minimizing both the number and length of looks, you will be helping us to evaluate the design of the charts.

Do you have any questions?

APPENDIX I

PILOT COMMENTS

Pilot Comments

Comments from each of the ten pilots are organized by topic. The experimenter's questions are shown in bold italics. The authors edited the grammar in some of the comments to make them easier to read. In some cases, words were inserted to clarify the comments. These edits and insertions are shown in brackets.

"Which chart did you prefer for answering the first [quick reference] question (frequency of the VOR, approach course, altitude at the final approach fix) - the NOS, the prototype, or no preference?"

New [prototype] chart. All information [was] in order when asked the question. Other [NOS] chart - had to look around.

Prototype. All the information. The most important information has a consistent location on the map. Drawn out the information.

Prototype. Because everything is in line. Vital information is in the top line. That's the highest priority - in the top line. You really need that information.

Prototype. Easier because it identifies the facility for the approach and the third [altitude at the FAF] box. Approach course is easy to find on either chart, so that wasn't a big addition.

Definitely the prototype was better, because it was right there in a line for you. Didn't have to look in more than one spot.

Prototype. Information was easily found and easy to read.

Prototype was better because it was an easier sequence to get the information off of the chart.

Prototype, because the essential information is on the top of the chart, you don't have to scan all over the chart to find out what you need.

Prototype - definitely. Because the information is much more easily accessible on the top line
Definitely the prototype, because the information was more easily or quickly accessible.

"Which chart did you prefer for reviewing the approach - the NOS, the prototype, or no preference?"

Neither [no preference]. I did like how the approach lighting box is set off. That is helpful. I would never be able to find it in the NOS.

Prototype. Any airport, you need to know what lights to look for. The lighting sketch at the top helps. Briefed the icons easier.

Prototype. Because they are bunched in accordance. You don't have to look all over the chart. Frequencies are straight across. Very good.

Prototype. Notes are easier to find and I always read the notes to brief. I really use the profile view to brief.

No preference, except for briefing the missed approach. It was much easier to brief the prototype.

Prototype. Because the information I need you can find more easily on the prototype than the NOS. I mainly look at the profile view [for the] inbound course. The missed approach instructions were easier to brief because of the icons. The [communication] frequencies were much easier to find across the top. Notes were easier to find at the top.

NOS because I'm used to it.

Prototype, because the essential information you need for briefing is on the top and in the missed approach instructions, the icons are much more clear.

Prototype, because the layout was more clear - top three lines and briefing the missed approach instructions. I like the notes all in one spot instead of scattered.

I still prefer the prototype, because I felt as though the important information was more easily accessible and stood out more. [It was] less congested. [When I was reviewing the prototype] I found I would use the information at the top and the profile. In the profile it was much easier to brief with the icons, and the missed approach [depiction] is visual [pictorial] so I don't have to take the time to read.

"Which chart did you prefer for executing the approach - the NOS, the prototype, or no preference?"

Prototype. Final approach course is boxed on plan view & clearer which navaid the approach is based [upon]. Clear because it [final approach course] is in the quick reference line first.

No preference.

Prototype. Boxes & bold lettering - liked that. Bold lettering makes information stand out.

About the same [no preference].

No preference. Usually use only the profile [view]. The only difference was box[ed final approach course] & box[ing the final approach course] didn't make much difference. Can't tell really if bolding [the MDA and/or missed approach holding fix] helped.

No preference.

Prototype. I like how the approach course is boxed in. Boxing helps in the profile and plan views. Also liked the bolding [of the MDAs] in the minimums.

Prototype. During a high workload situation, the information is much more clear. I like the frequencies where they are [on the prototype], the only thing is I think the frequencies should go vertically, but in boxes. I like how they are on the Jeppesen charts.

Prototype. I use the profile view to execute [the approach]. Boxing makes the approach course stand out more. Otherwise, not a lot of difference.

The prototype for the same reasons as I mentioned before - [the important information was more easily accessible and stood out more. [It was] less congested. [When I was reviewing the prototype] I found I would use the information at the top and the profile.]

"Which chart did you prefer for executing the missed approach procedures - the NOS, the prototype, or no preference?"

Prototype. Icons were really really good. Always used the icons. Only thing that wasn't iconized was the missed approach holding point. I had to go to the text to find out how far out you fly the radial. Have to look somewhere else to complete the missed approach. I would like to see another icon with the intersection (INISH LAX 12) in the icon row. Then I would never have to look up in the text row at all.

Prototype. Big difference. Icons are much more useful. Can get a 3D [3 dimensional] view of what you need to do in the blink of the eye.

Prototype. The best contribution, best improvement to [the] entire chart is the icons. [They are] very clear.

Prototype. Really like the icons. Easier to quickly get information, but it is missing two things. [1.] Needs to tell you which way to turn when you get to the intercept. Needs to tell you what to do. One more box would do it. [2.] Would like the name of the missed approach fix [placed] in the profile view at the tip of the [missed approach] arrow.

Prototype. Without a doubt the icons are the way to go.

Definitely the prototype. Altitudes and headings much easier to find and read. Liked the bolding. Bolding the missed approach fix bold didn't help enough. It didn't stand out enough.

Prototype. Because I think the icons help you pull the information quickly, rather than having to read it off the plate.

I prefer the prototype. The icons make it much easier to obtain the information.

I really like the icons, but I [would] also like the text in with the icons. I felt like I had to look back and forth between the icons and text. I had to look to the text for the holding fix. If you could put that down with the icons I would never have to go back to the text. Up to that point, the prototype was great.

Definitely the prototype, and I never read the paragraph, I always looked at the icons. I would get the missed approach holding fix from the plan view.

"What features of the prototype chart did you not use?"

Airport Elevation

Airport elevation - always looked at airport sketch.

Didn't use airport elevation. Didn't need it in the new location. Got it from the airport sketch.

Airport elevation - easier to go to the airport sketch.

Airport elevation - I looked at airport sketch.

Airport elevation - I used the airport sketch.

Airport elevation - I went to the airport sketch.

Final Approach Fix Information

[I would go to the profile view for the] final approach fix altitude.

Got final approach fix from profile view.

Altitude at final approach fix - when briefing, I looked at the profile to find it. I only looked up top to answer the first [quick reference] question to find it.

Easy to find crossing altitude [altitude at the FAF] in the profile view.

When doing approach after the first [quick reference] question I would use the profile view to get the first three pieces of information [the frequency of the (VOR or NDB) that serves the approach, the final approach course, and the altitude at the final approach fix] on the top line. (Note: this comment addresses three information items. Therefore, it is also listed in the Final Approach Course and Frequency of the (VOR or NDB) That Serves the Approach sections below).

Final Approach Course

For the final approach course heading I went to the profile view.

Got the inbound course from the profile.

For ["What is the final approach course?"] I went down [to the profile view].

Final approach course [shown on the top line in the briefing strip]. I would sometimes go down to the profile view and it is boxed down there so I didn't need to use the top line.

When doing approach after the first [quick reference] question I would use the profile view to get the first three pieces of information [the frequency of the (VOR or NDB) that serves the approach, the final approach course, and the altitude at the final approach fix] on the top line. (Note: this comment addresses three information items. Therefore, it is also listed in the Final Approach Fix Information section above and the Frequency of the (VOR or NDB) That Serves the Approach section below).

Approach Lighting

Also used the airport sketch for the approach lighting.

Frequency of the (VOR or NDB) That Serves the Approach

When doing approach after the first [quick reference] question I would use the profile view to get the first three pieces of information [the frequency of the (VOR or NDB) that serves the approach, the final approach course, and the altitude at the final approach fix] on the top line. (Note: this comment addresses three information items. Therefore, it is also listed in the Final Approach Fix Information and Final Approach Course sections above).

"Do you have any other comments?"

Briefing Strip

Used entire top row [on the prototype]. I really like the new top row especially. All three top rows are very important for consistency.

Really liked the quick reference line.

Used [approach] lighting [sketch] up top. Liked that.

Would prefer to see communication frequencies [formatted] vertical with boxes. Maybe because I'm used to Jeppesen where they are [formatted] vertical in a box.

I'm used to Jeppesen charts and they have [information about the primary navaid that serves the approach] at the top of the chart. [On NOS charts] it's hard to find the primary navaid [in the plan view] that serves the approach. Would like to see the improved [prototype] version. It stands out more. In the new [prototype] version I like it because it does stand out. I used the [approach] lighting [sketch] up top. I liked that.

Easy to see left to right [on the prototype] rather than vertically.

I really like the TDZE up top [on the prototype] - always looked there.

I like having the primary navaid information at top [of the prototype chart]. I really like the way the frequencies are arranged [horizontally on the prototype] much better.

I like the lighting sketch at the top [of the prototype] too.

I continuously looked down on the bottom [on the prototype] for the notes. Probably because I'm used to searching for them on the bottom.

It is much more useful seeing the touchdown zone elevation next to the airport elevation [as shown on the prototype]. On the NOS charts, it is a real search to find the touchdown zone elevation.

I got all information from the new place [briefing strip]. That was probably because I wouldn't have to look down as far to the bottom of the chart, for example on the airport sketch. I could get it right off the top three lines.

Highlighting Text with Bolding and Boxing

Liked missed approach holding fix. Like the bold [text]. Would like to see it boxed also.

Liked the bold print.

Bolding didn't do anything. Did not really help. Approach course sticks out already because it was in the middle of the line. No need to box it.

Bolding [the MDA or missed approach holding point on the prototype] didn't make a lot of difference but [that] may be because of the shutter.

Frequencies are easy to read in the bold [on the prototype].

Bolded numbers are helpful for initial altitude for missed [approach procedures] and MDAs.

The approach course I would usually get from profile view. Really easy to pick it up because it is boxed in profile view.

I would like to see the final approach course on the plan view drawn out [highlighted] more. Maybe more bolded. Boxing the [final approach] course helped.

MSA Circle

I prefer the radials for the MSA [on the prototype].

For MSA circle preferred the text in prototype version, not NOS symbols.

Prefer the prototype for the MSA circle. Prefer the text and sectors. Helps you double check the primary navaid.

I like the radials in the MSA circle [on the prototype]. I may be used to the old way, it may take awhile to recondition myself to do it but I think it's a better method. I like the text in the center [of the MSA circle on the prototype].

MSA circle - I prefer the bearings. I also prefer the text in the center of the circle [as shown on the prototype]. I like it how it is on the prototype chart.

I prefer the radials to the bearings [in the MSA circle] - it is more intuitive. [Whether or not the symbol] or the text [was given] in the MSA circle didn't make any difference.

Iconic Missed Approach Instructions

Really liked the icons.